RESEARCH OF FLATNESS DEFECTS FORMING AT 20-HI STEEL STRIPS ROLLING MILL

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ABSTRACT

Results of researches of strips flatness from corrosion steels on the20-hi rolling mill 1700 are presented for central and edges wavinesses type „fur-tree". The mathematical model for defects of a strip - „fur-tree" is developed. Recommendations for prevention of local defects on the strip, type „fur-tree" by the 20-rolling mill 1700 are created for integrated iron-and-steel works.

Keywords: cold rolling, strip, corrosion, steels, 20 hi rolling mill, defects of flatness, waviness.

INTRODUCTION

The flatness of strips from corrosion steel is one of the major figures of quality of cold rolled strips [1]. The grade of conformity of flatness quantitatively is defined by the relevant valid standards.

For example, in accordance with GOST 19904-90 for thin cold rolled steel strips with width 1000 - 1500 mm, the flatness normal is to 15 mm, when improved it is up to 12 mm [2].

The users of strips and sheets for punching technology prefer this type of steel. The automated complexes for producing of strips and sheet products offer wide applications. In Russia there is the constant trend to raise efficiency of production of strips from corrosion steel with width to 1000 mm and abroad to 1250 mm. This trend is connected with decrease of thickness to 0,5 - 0,7 mm. The weight of initial rolls can reach up to 15 Mg, and the speed of rolling - up to 10 m/s. The production technology regularly creates asymmetrical type "fur-tree" into the steel strips. This is very important to reduce this defect as much as possible, and the final quality of the produced strips to be constantly good. Therefore works on problems of flatness of strips from corrosion steels, rolled on modern high-duty camps, are very important and actual [3 - 8].

EXPERIMENTAL

Now for manufacture of thin cold rolled corrosion steel strips is used the 20 hi rolling mill [3]. One of essential advantages of 20 hi rolling mill is combination of high rigidity rolls and frames [4]. However, when rolling thin and wide strips sometimes can be observed deformations and non flatness formations.

The main type of non flatness of stripe appear usually into the central part and on the edges of material and this non flatness is called "fur-tree", and type of longitude buckling.

The main reason of loss of stability of flatness of cold rolling strips is unregular deformation of some spots on the width [5].

On the 20 hi rolling mill irregularity of deformation appears on bandwidth because of non presiced adjustments of the mill rolls, and also because of unproper used profiles with different unsuitable parameters for rolling. Conditions of straining of strips are influenced by different reasons like change of the rolls temperature in process of cold rolling, change of homogeneity of the mechanical structures, friction on bandwidth, and a spotty wear on the barrels of the working rolls.

On the 20 hi rolling mill 1700 integrated iron-and-steel works waveness can not be easy reduced into the central part of strips in comparison of edges. The reasons are excessive heating of rolls, insufficient reduction in pass, wrong set-up of a mill, unproper profile. The reason of edge waviness is a big reduction of edges of strip in comparison of its center because of wrong mill set-up and the spotty wear of barrels of working rolls.

Results reached for rolling strips from corrosion steel with thickness of 0,5 - 0,7 mm and width 1000 – 1250 mm. The amplitude of the central waviness prodused by the 20 hi rolling mill 1700 is 10 - 12 mm, and the wave length 900 - 1000 mm, the amplitude at the edge waviness is 8 - 10 mm and the wave length 1000 - 1200 mm.

The 20 hi rolling mill 1700 has following technical data:

- Force of rolling, MN 1-5
- The maximum tension on reels, KN 500
- Speed of rolling, m/s 0,5 - 4,0
- Temperature of a chilling liquid, ºC 37 - 42
- Thickness of rolling strips, mm 0,3 - 0,7
- Width of rolling strips, mm 800 - 1500
- Diameter of a work roll, mm 90 (75 - 105)
- Power of the electric motor, kw 2×1840

The stand of the 20 hi rolling mill 1700 consists of: eight back-up rolls with rolling-contact bearings; six second intermediate rolls, from which four - power-driven; four first intermediate back-up rolls; two working rolls; the overhead and bottom screw-down mechanism, and also the mechanism for adjustment of rolls profile.

Depending on the required width of the rolling steel strips a level of quality can be achieved by using cylindrical or convex working rolls.

RESULTS AND DISCUSSION

First intermediate rolls are applied with single-sided taper. For strips with width 950 - 1280 mm are applied rolls with length of a cone part 645 mm with depth of 0,84 mm taper. The strip flatness can be regulated and the best results can be achieved by the bend of axes with the block bearings. Thus the bend of axes rolls occurs through moving of seven supports of the toothed bars connected to toothed quadrants of eccentric rings 0,762 mm having an eccentricity. As a result of individual act on each of supports of the mechanism, and the bend of axes on length of back-up rolls, thus improve the flatness on the whole width of the rolling strips.

At rolling of thin strips on the 20 hi rolling mill defects type of the „fur-tree“ (Fig. 1) sometimes can be found.

The analysis provided on the 20 hi rolling mill 1700 especially for strips of corrosion steels, shows that defect „fur-tree“ appears on the bandwidth in the middle at an

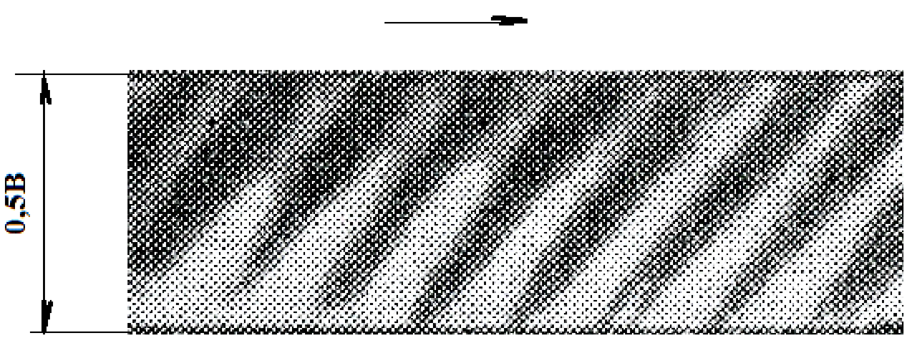

Fig. 1. Defect of the form of a strip „fur-tree“ at rolling.

Table 1. Parameters of the “fur-tree” defects at strips rolled from corrosion steels on the 20 hi rolling mill 1700 (h_1 = 0,5 mm, B = 1030 mm).

№	*A*, mm	*L*, mm	*A*/*L*	Form
1	0,1	50	0,0020	"fur-tree"
2	0,2	30	0,0066	"fur-tree"
3	1,0	40	0,0025	"fur-tree"
4	5,0	50	0,1000	"fur-tree"

angle 45 - 55° to the rolling axis, taking place on 50 – 60 % of bandwidth. The length of period -L, between separate segments is between 30 to 50 mm, the altitude of segments (wave) (Table 1) in that case is 0,1 to 5 mm.

Table 1 shows the altitude of a wave colling axis.

“Fur-tree”, as a rule, is ff defect “fur-tree” changes from 0,1 to 5,0 mm, and the period of the length between separate segments is 30 to 50 mm.

The defect “fur-tree” can be single-sided, that is turned in one part of the rolling axis, and two-sided, that is turned on both parts of the rolling axis. This defect is formed as a rule on strip with thickness less than 0,7 mm and width more than 1000 mm at a reduction of 8 - 15 %.

Presumably in the cold rolling on the 20 hi rolling mill 1700 one of the reasons of formation of defect “fur-tree” is a cross transfer of rolling. Therefore for flatness improvement of cold-rolled strips first of all it is necessary to improve quality of thickness, namely to reduce transverse thickness variation and stabilize the profile.

The transverse thickness variation of hot-rolled strips from corrosion steels with thickness 6 – 8 mm on the end of a continuous mill 1700 is 0,1 - 0,3 mm, the transverse flatness of thickness of strips 1,5 - 3 mm after the first cold rolling on the 4 hi rolling mill is 0,03 - 0,05 mm, and after the second cold rolling is 0,01 - 0,02 mm.

The researches showed that the main cause of unsatisfactory of profile quality of hot-rolled strips is deterioration of working rolls of hot stands. During the rolling process the strip cross profile essentially changes from convexity of 0,1 mm at the beginning of the rolling to 0,3 mm in the second half of the process. Thus the strip profile has local roughness of 0,03 - 0,04 mm. Considerable oscillations of the transverse thickness do not provide a constancy of conditions of a straining at the first cold rolling and the relevant instability of the transverse thickness is realized at the first and second cold rolling process. As a result the general character of change of cross profile of strips after the first and second cold rolling process remains unchanged.

The rolling schedule of steel strips on the 20 hi rolling mill 1700 is presented in Table 2.

Applied on the 20 hi rolling mill 1700 cold rolling process (Table 2) shows that existing considerable instability of the transverse of thickness of semifinished product and irrational set-up of mill is leading to the deformation type „fur-tree“ on the end part of the strip.

The qualitative analysis of the reasons and calculation of parameters of defect „fur-tree“ demands to work out a mathematical model of formation of this non flatness strip complicated defects.

The circuit design of formation of defect on the strip „fur-tree“ is presented on Fig. 2.

At rolling when the segment of defect „fur-tree“ on the fast-head end of a strip speed of metal is formed, it can be written down (Fig. 3)

$$V = \sqrt{V_{X^2} + V_{Z^2}} \quad (1)$$

Table 2. Rolling schedule of steel strips 12X18 H10T on the 20 hi rolling mill 1700.

h_0, mm	h_1, mm	ε, %	T_0, kN	T_1, kN	*P*, MN
0,93	0,73	25	180	140	4,1
0,73	0,62	15	160	120	4,3
0,62	0,54	12	140	130	4,5
0,54	0,49	9	53	50	4,7

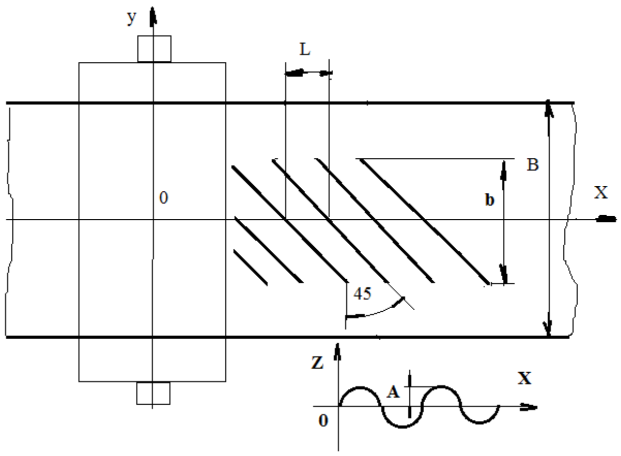

Fig. 2. The circuit design of formation of defect „fur-tree“ on the fast-head end of a strip.

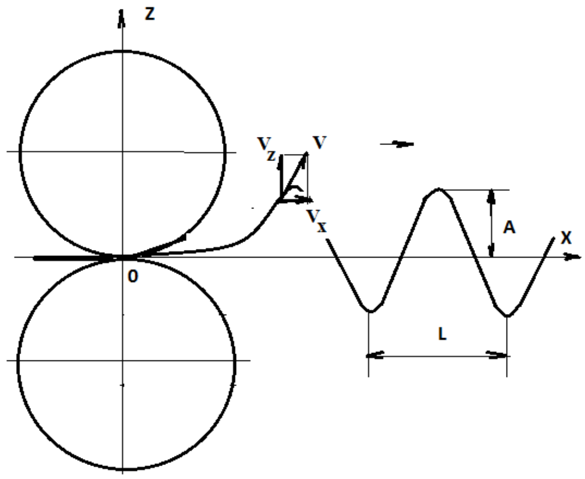

Fig. 3. The longitudinal and vertical speeds strips at formation of defect “fur-tree”.

where: V_X, V_Z - the longitudinal and vertical speed of strip at formation of defect “fur-tree”.

The longitudinal component of the speed of a strip can be presented as:

$$V_X = (1 - \frac{x}{L})\Delta V_1, \quad (2)$$

where: ΔV_1 - the maximum difference of the longitudinal speed between flat regional section $V_к$ and a section on middle V_c of a strip in a plane of an exit from the deformation nucleation site for; L - length of the period of defect “fur-tree”.

Dependence (2) leads to the following boundary conditions

$$x = 0\,, V_x = \Delta V_1\,, x = L, V_x = 0 \quad (3)$$

The vertical component of the speed of metal on a section of formation of defect “fur-tree” we write down in

$$V_Z = V_X \frac{\partial W}{\partial X}. \quad (4)$$

The change of a surface a “fur-tree” is provided:

$$W = A\, \mathrm{Sin}\frac{\pi y}{b}\, \mathrm{Sin}\, \frac{\pi\,(x - \mathrm{k}y)}{L} \quad (5)$$

where: b - width of defect of fur-tree; k - the factor, characterizing a slope of defect “fur-tree” in an axis of rolling, k = 1 for an angle 45º.

The last equation after differentiation is

$$\frac{\partial W}{\partial x} = \frac{\pi A}{L}\, \mathrm{Sin}\frac{\pi y}{b}\, \mathrm{Sin}\, \frac{\pi}{L}(x - k\, y) \quad (6)$$

Substituting eq. (6) in eq. (4), we gain

$$V_Z = (1 - \frac{X}{L})\, \Delta V_1\, \frac{\pi A}{L}\, \mathrm{Sin}\frac{\pi y}{b}\, \mathrm{Sin}\, \frac{\pi}{L}(x - k\, y). \quad (7)$$

The intensity of speeds of shear strains is given as [6]:

$$H = \sqrt{2/3}\sqrt{(\xi_X - \xi_y)^2 + (\xi_y - \xi)^2 + (\xi_Z - \xi_X)^2 + 3/2\,(\eta^{2Xy} + \eta^{2yZ} + \eta^{2ZX})} \quad (8)$$

By means of known relationships of the theory of plasticity it is definable necessary components of tensor of speeds of deformations

$$\xi_X = \frac{\partial V_X}{\partial x} = -\frac{\Delta V_1}{L}, \xi_y = 0\,, \xi_Z = 0,$$

$$\eta_{YZ} = \frac{\partial V_y}{\partial Z} + \frac{\partial V_Z}{\partial y} = \frac{\pi^2 A\, \Delta V_1}{b\, L}\,(1 - \frac{X}{L})\, \mathrm{Cos}\frac{\pi y}{b}\, \mathrm{Cos}\, \frac{\pi}{L}(X - \mathrm{ky}) - \quad (9)$$

$$-\frac{k\, A\pi\, \Delta V_1}{L}\,(1 - \frac{X}{L})\, \mathrm{Sin}\frac{\pi y}{b}\, \mathrm{Sin}\, \frac{\pi}{L}(X - \mathrm{ky})$$

$$\eta_{ZX} = \frac{\partial V_Z}{\partial X} + \frac{\partial V_X}{\partial Z} = -\frac{\pi A \pi \Delta V_1}{L^2}\, \mathrm{Sin}\, \frac{\pi y}{b}\, \mathrm{Cos}\frac{\pi}{L}(X - k\, y) +$$

$$+(1 - \frac{X}{L})\frac{\pi A \pi \Delta V_1}{L}\, \mathrm{Sin}\, \frac{\pi y}{b}\, \mathrm{Sin}\frac{\pi}{L}(X - k\, y)\cdot$$

Power for changing of “fur-tree” defect can be written as [6]

$$N_{\Phi} = b \int_0^A \int_0^L \mathrm{THdxdz}, \tag{10}$$

where: $T = \tau_S = \text{const}$ - for rigidly plastic medium; H - intensity of speeds of shear strains; b - width of defect "fur-tree".

Taking into account eq. (9) the power form becomes

$$N_{\Phi} = \tau_S \mathrm{bA}\,[\,5{,}33\frac{\Delta V_1 A}{L} + 1{,}33\frac{\Delta V_1 A^3}{L^3} + 4\Delta V_1 A^2 \;/L^2] \tag{11}$$

where: $\Delta V_1 = V_{1C} - V_{1K}$;$V_{1C}, V_{1K}$ - the longitudinal strip speed on the rolls exit accordingly along the edges and the strip middle.

The longitudinal outlet velocity V_{1i} for a section i (with,) on bandwidth is computed with use, known of the rolling theory, the equation is:

$$V_{1i} = V_{в}\,(1 + S_i), \tag{12}$$

where: $V_в$ - rolls speed, $V_в = \omega R_i$, ω - a peripheral rolls velocity; S_i - a strip advancing, $S_i = \gamma_i^2 (R_i/h_i)$; R_i - the rolling rolls radius; γ_i - an angle of neutral cross-section $\gamma_i = \frac{\sqrt{\Delta h_i/R_i}}{2}\left(1 - \frac{\sqrt{\Delta h_i/R_i}}{2f_i}\right)$, Δh_i – thickness reduction in, f_i - factor of a contact friction (a friction angle).

For an investigated problem the variation of power of superposed forces is equal to null, therefore the condition of a minimum of total energy of deformation can be written as

$$\frac{\partial F}{\partial L} = \frac{\partial N_{\Phi}}{\partial L} = 0 \tag{13}$$

where: $F = N_{\Phi}$.

Hauling down mathematical manipulations, we gain

$$A = (0{,}002 - 0{,}125)\,L. \tag{14}$$

Parameters of defect of the form "fur-tree" for strips from a corrosion steel on the 20 hi rolling mill 1700 are presented on Fig. 4.

The analysis of the dependences presented on Fig. 4 shows that the divergence between theoretical and experimental data for strips from corrosion steel with thickness 0,4 mm to 0,6 mm, when rolled on the 20 hi rolling mill 1700, does not exceed 15 %.

It can be assumed that formation of defect "fur-tree" occurs because of unequal burning of metal strips and unequal longitudinal speed of metal on the band width. There are at least two main factors: the transverse thickness variation and non parallel displacement of working rolls sided one by one in a horizontal level.

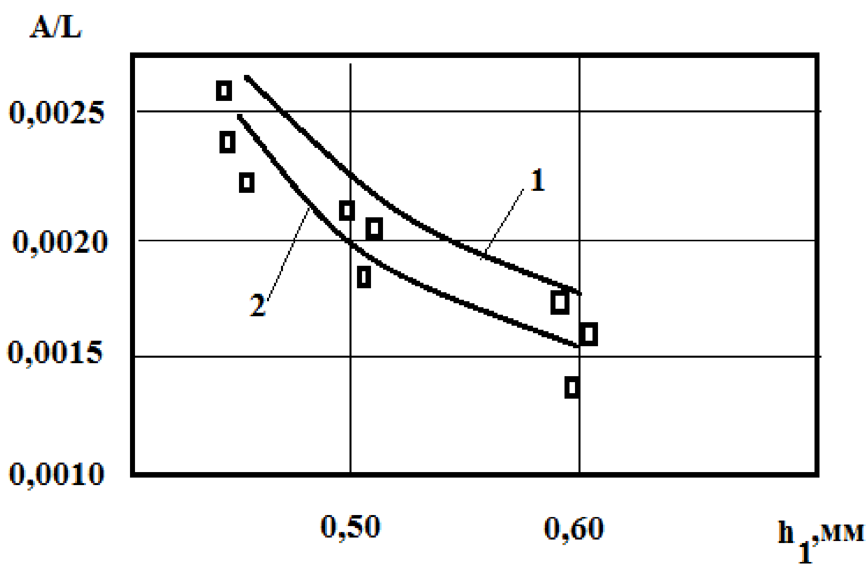

Fig. 4. Parameters of defect of "fur-tree" for strips from a corrosion steel on the 20 hi rolling mill 1700 (B = 1030 mm): 1 - calculation with eq. (14), 2 - empirical data.

As a result there is a shift of the central strip section to the relative part of edges on 45 - 55º and the defect “fur-tree” appears. The displacement of working rolls occurs because of un proper adjustment of the overhead and the bottom working rolls.

Shifting of the central section of strips relatively to the edges on the rolled strip section thus creat the compressed and shifting tensions leading to the defect “fur-tree”.

When rolling of thin and wide strips from corrosion steels on the 20 hi rolling mill 1700 for preventing of formation of defect “fur-tree” can be used the following recommendations:

- Increase of diameter of working rolls, this can lead to increase of the length of deformation advancing zone, and magnitude of flattering rolls which reduce the common irregularity on band width. Research shows that strips from corrosion steel rolling on the working rolls with diameter of 105 mm the defect “fur-tree” is much less if compared with the working rolls with diameter of 90 mm;
- Increase of first-head tension at strips rolling, the defect “fur-tree” concentrates on the edge sections of strip; on these sections there is an increase of zone of advancing, and the bending of critical line on bandwidth decreases. Researches showed that at rolling the third pass of the strips h_0 = 0,62 mm, h_1 = 0,54 mm (Table 2) when increase the first-head tension with 130 κN to 140 κN formation of defect “fur-tree” is much less, than at rolling with using of tension on actual set-up of a mill;
- Increase in a back tension leads to decrease of force of rolling. The research shows that the increasing of back tension slightly influences decreasing of formation of defect “fur-tree”.

CONCLUSIONS

On the reversible 20 hi rolling mill 1700 when rolling thin strips from corrosion steel the principal reasons taking place in formation of flatness “fur-tree” are revealed and ranges of its changes on altitude from 0,1 to 5 mm with length of the period from 30 to 50 mm are shown, which use allows to correct roll adjustment. There also is formulate demand for thickness variation of cold rolled products.

The mathematical model of “fur-tree” defect is created for the thin strips, considering irregularity on bandwidth concerning high-speed and deformation conditions of rolls, and also the importance of the diameter of the working rolls affecting flathness parameters.

On the basis of systematical theoretical and experimental researches recommendations for the right selection of the diameter of working rolls, thickness variations and adjustment of the 20 hi rolling mill 1700 are given for production without defect “fur-tree”.

REFERENCES

1. B.N. Matveev, Sheet stainless steels, The Steel, 5, 2013, 56-60.
2. Rolling on 20 hi rolling mill 1700, P.I. Poluhin, V.P. Poluhin, A.F. Pimenov (Eds.), Moscow, Metallurgy, 1981, (in Russian).
3. A.G. Babkin, V.N. Larin, N.V. Nikitin, Production technology cold corrosion hire from steel of 400 series ASTM 240/240M, Steel, 2013, 3, 39-40, (in Russian).
4. V.P. Poluhin, S.A. Stukalov, G.V. Ashihmin, Increasing of accuracy of rolling of tapes from precision alloys on 20 hi rolling mill 400, Flowage of metals and alloys, MISIS, № 140, Moscow, “Metallurgy”, 1982, 91-95, (in Russian).
5. E.A. Maksimov, R.L. Shatalov, N.S. Boshamdzhiev, Manufacture of tablet strips at rolling, Heating Engineer, Moscow, 2008, (in Russian).
6. V.N. Vydrin, A.S. Fedoseenko, V.I. Krajnov, Process of continuous rolling, Moscow, Metallurgy, 1970, (in Russian).
7. I. Mazur, T. Koinov, Quality control system for a hot-rolled metal surface, Journal of Chemical Technology and Metallurgy, 49, 1, 2014, 71-76.
8. T. Koinov, R. Shatalov, Plastic deformation, Sofia, Avangard prima, 2008, p.346, (in Bulgarian).