A. KOZHEVNIKOV, I. KOZHEVNIKOVA, N. BOLOBANOVA, A. SMIRNOV

ISSN 0543-5846
METABK 59(1) 55-58 (2020)
UDC – UDK 669.14.018-621.41:621.771/621.5:534.83:658.281-621.14=111

CHATTER PREVENTION IN STANDS OF CONTINUOUS COLD ROLLING MILLS

Received – Primljeno: 2019-05-24
Accepted – Prihvaćeno: 2019-07-25
Original Scientific Paper – Izvorni znanstveni rad

The article states new results of the theoretical and applied research on prevention of chatter in stands of continuous cold rolling mills. It was found that chatter occurs under those process conditions, which involve violation of a condition of strip rolling with tension because of ongoing change of the process state, when the process proceeds now with tension and now with pushing because of variation of strip volumes per second in a negative or positive range of values. It is demonstrated that it is possible to influence effectively the difference of strip volumes per second and prevent chatter by decreasing reduction in a stand subject to chattering and simultaneously increasing reduction in adjacent stands, and also by changing the ratio of rolling speeds in these stands of the mill. This has led to development of process conditions for thin steel strip rolling on the 5-stand mill 1700 of PAO Severstal, enabling rolling speed increase and process stabilization.

Key words: steel strip, cold rolling, chatter prevention, continuous mill stand, rolling mode

INTRODUCTION

Chatter during rolling has a negative impact on a thin steel strip and equipment of continuous rolling mills, prevents mastering rolling speeds, and therefore equipment performance improvement.

In the current circumstances of cold rolled strips production, chatter is observed at mills of many steel works [1 - 8], at the same time there is no universal solution of this problem, moreover, there is also no explanation of its origination.

In several studies [9 - 11], torsional vibrations in a drive line are identified as main causes of chatter. In paper [12], vibration origination and development in a work stand is related to thermal decomposition of lubrication resulting in deterioration of friction conditions and uneven increase of rolling force causing shift of rolls. The paper [13] represents a hypothesis that the reason of chatter is cavitation and destruction of the coolant. The authors [14] consider that the strip itself (its vibration) is the source of chatter. In papers [15, 16], an unstable position of work rolls in a horizontal direction is indicated as the reason of resonant vibrations.

Key measures to prevent chatter are related to rolling speed reduction or to changes in equipment design and parameters for vibration dumping [4 - 7].

In this regard, studies on chatter prevention and provision of chatter resistance of the thin strip cold rolling process are of great scientific and practical importance.

A. Kozhevnikov – Corresponding author – E-mail: avk7777@bk.ru
I. Kozhevnikova, N. Bolobanova, A. Smirnov: Cherepovets State University, Cherepovets, Russia

RESEARCH METHODOLOGY

The study and identification of factors resulting in chatter were carried out on 20 randomly selected rolling modes for strips of 08ps (Rus. “08пс”) steel grade with the thickness of 0,45 mm and width of 915 mm, for which the 5-stand mill 1700 automated data measurement and control system detected chatter. Besides, parameters of rolling modes of 20 strips of 08ps steel grade of similar shape, in which no chatter occurred, were also considered.

Parameters of each mode were evaluated in accordance with the sequence used for analysis of the mode represented in Table 1.

The data control system of the mill recorded resonant vibration three times in the stand 4 during rolling according to the mode of Table 1, and the rolling speed oscillogram (Figure 1) shows that mill operators dropped the speed from 15 m/s to 11 m/s to prevent chatter development to dangerous levels.

Table 1 **Actual rolling mode of the strip of 08ps steel grade with the dimensions of 2,0→0,45 × 915 mm**

Stand No.	υ_i / m/s	h_i / mm	ε_i / %	σ_i / MPa
1	4,48	1,399	30,05	171
2	6,56	0,98	30	201
3	9,62	0,681	30,5	209
4	14,15	0,47	30,96	209
5	14,65	0,455	3,2	-

Note. υ_i – rolling speed in the stand i; h_i – strip thickness; ε_i – individual percent reduction of the strip; σ_i – strip tension.

The study of actual changes in process parameters of the deformation mode demonstrated that variations of

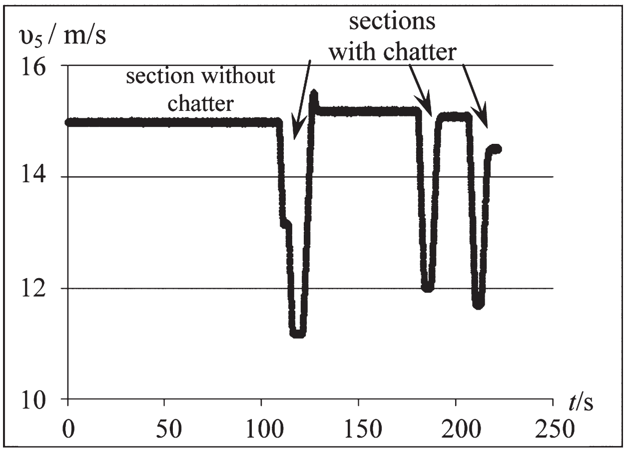

Figure 1 The graph of changes in rolling speed when self-vibration occurs

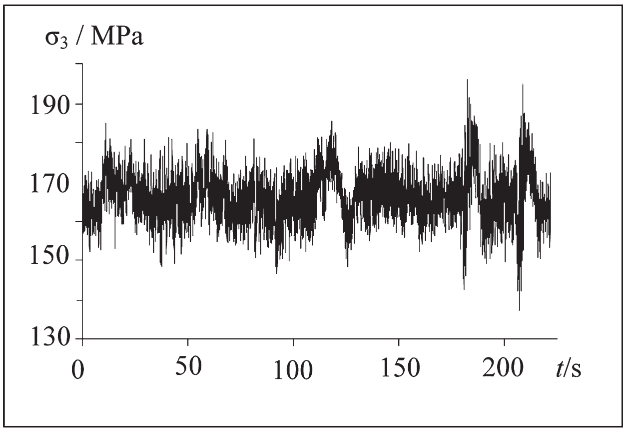

Figure 2 Actual variation in specific tension in the 3rd interstand space

strip tension in the third and fourth interstand spaces occur 5 to 6 seconds before the active phase of chatter and amount to 20 to 25 % of nominal values (Figure 2). It results in variation of rolling forces, and respectively of percent reduction in the stand 4 up to 15 to 20 %.

In order to stabilize the rolling process, the system for automatic regulation of thickness and tension works out these deviations by changing speed in stands 1 to 3. This results in violation of a condition of strip rolling with tension:

$$V_1 < \ldots < V_i < \ldots < V_n, \quad (1)$$

where V_i – strip volume per second in the stand i ($i = 1 \div n$):

$$V_i = \upsilon_i \cdot F_i, \quad (2)$$

where F_i is the cross sectional area of the strip at the exit from rolls of the stand i.

At the same time, the rolls of the stand 3 now push the strip (pushing) and now pull it out (tension) of work rolls of the stand 4, which is confirmed by graphs of changes in difference of strip volumes per second (ΔV_{3-4}), rolled in stands 3 (V_3) and 4 (V_4), plotted considering variations in process parameters (Figure 3). Variations in the specified parameter exceed its average value more than 3 times, which results in origination and development of resonant vibrations in rolling stands.

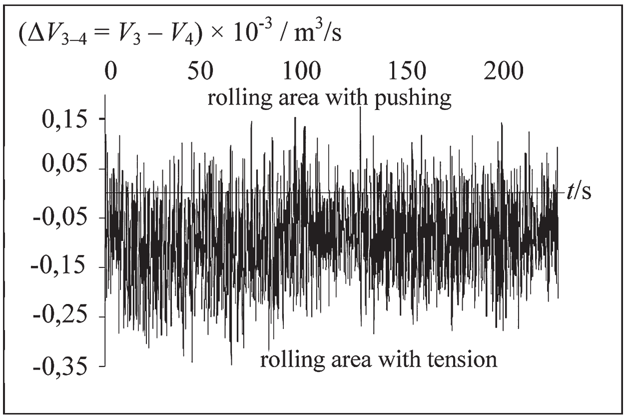

Figure 3 The graph of the difference in steel volume rolled per a time unit in stands 3 and 4

Rolling modes without chatter differed in the fact that graphs of ΔV variance for adjacent work stands were either strictly in the positive area of the graph (Figure 3), typical for deformation conditions with pushing, or in the negative area typical for deformation with tension. The rolling speed at these modes did not exceed 12 m/s, which made it impossible to produce the considered product range with required output.

The analysis of formulas (1) and (2) demonstrated that it is possible to influence effectively the difference of strip volumes per second and prevent chatter by decreasing reduction in a stand subject to chattering and simultaneously increasing reduction in adjacent stands, and also by changing the ratio of rolling speeds in these stands. The latter is determined by the constant of continuous rolling.

Thus, in order to prevent chatter it is required to change deformation-speed rolling modes according to the criteria based on changes in difference of volumes per second in adjacent stands.

SIMULATION AND TEST RESULTS

The analytical simulation of the operating practice provided in Table 1 in order to ensure the strip deformation condition only with tension consisted of the following stages.

The first stage included correction of reduction. Reduction in the stand 4 was reduced from 31 % to 28 % due to reduction increase in stands 3 and 5, which provided ΔV_{3-4} graph to be strictly negative in the reference frame. It should be mentioned that simulation of strip thickness variation at the exit from stands 3 and 4 was performed during research according to the normal law of distribution with deviation from the average value of ± 2 %.

The second stage included analysis of the ratio of the rolling speed in adjacent stands – $\frac{\upsilon_2}{\upsilon_1}$, $\frac{\upsilon_3}{\upsilon_2}$, $\frac{\upsilon_4}{\upsilon_3}$. The results indicated that the ratio $\frac{\upsilon_4}{\upsilon_3}$ = 1,465 - 1,47 is critical for the considered section size.

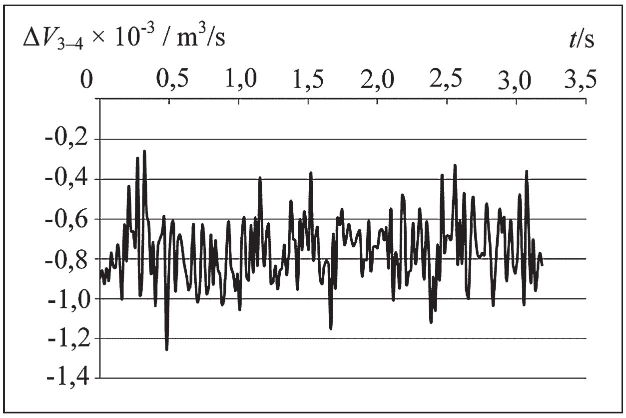

Figure 4 The graph of change in difference of steel volume per second during rolling according to the suggested mode

In order to prevent resonant self-vibration and to improve mill production capacity it is necessary to increase this ratio and the rolling speed in the stand 4.

The optimal speed value of υ_4 = 16 m/s and the ratio $\frac{\upsilon_4}{\upsilon_3}$ = 1,6 (simulation of rolling speed variation was carried out according to the normal law with the deviation of ± 5 %) were detected during simulation.

The third stage included the study of changes in difference of strip volumes per second during rolling according to the mode (Table 2) based on simulation results: percent reduction in the stand 4 was reduced to 28 %, the rolling speed was increased to 16 m/s, and, as a result, the strip speed at the exit from the mill was increased to 17 m/s, that is by 14 %.

Table 2 **Suggested rolling mode of the strip of 08ps steel grade with the dimensions of 2,0→0,45 × 915 mm**

Stand No.	υ_i / m/s	h_i / mm	ε_i / %	σ_i / MPa	V_i / m^3
1	4	1,4	30	140	5,1×10^{-3}
2	6,25	0,98	30	158	5,6×10^{-3}
3	10	0,66	32,6	170	6,04×10^{-3}
4	16	0,475	28	176	6,95×10^{-3}
5	17	0,45	5	-	7×10^{-3}

Figure 4 has the graph of $\Delta V_{3\text{–}4}$ change showing that selected process parameters provide a stable strip rolling process with tension.

The rolling mode represented in Table 2 was tested on the operating 5-stand continuous rolling mill 1700 of PAO Severstal during rolling of six coils from the same heat. The process speed was at the level of 17 m/s throughout the experiment when rolling all six coils without a threat of resonant vibrations.

CONCLUSION

The study finds that resonant self-vibrations in work stands of continuous mills originate under process conditions accompanied by alternation of strip rolling conditions with tension and with pushing.

In order to exclude the possibility of chatter origination and development, it is required to determine deformation-speed modes providing the rolling process strictly in the area of pushing, or strictly in the area of tension.

The suggested solution to prevent chatter in stands of continuous cold rolling mills shall be used in development of new process conditions and in correction of existing ones based on the constant of continuous rolling.

Developed process conditions for rolling thin steel strips considering changes in difference of volumes per second in adjacent work stands made it possible to stabilize the process and increase the rolling speed at the 5-stand mill 1700 of PAO Severstal.

Acknowledgements

This research was financially supported by the Ministry of Education and Science of the Russian Federation within the framework of the project part of the state task of Cherepovets State University (No. 11.3943.2017/4.6).

REFERENCES

[1] I. Yarita, K. Furukawa, Y. Seino, An analysis of chattering in cold rolling of ultrathin gauge steel strip, Transactions ISIJ 19 (1978) 1, 1-10.

[2] L. Chefneux, J.-P. Fischbach, J. Gouzou, Study and control of chatter in cold rolling, Iron and Steel Engineer (1980), 17-26.

[3] P.H. Hu, K.F. Ehmann, Analysis of Chatter on a Tandem Rolling Mill, International Journal of Manufacturing Processes (2000) 4, 217-224.

[4] B.R. Hardwick, A Technique for the Detection and Measurement of Chatter Marks on Roll Surfaces, Steel Technology (2003) 4, 64-70.

[5] Y. Kimura, Y. Sodani, N. Nishiura, N. Ikeuchi, Y. Mihara, Analysis of Chatter in Tandem Cold Rolling Mills, ISIJ Int 43 (2003) 1, 77-84.

[6] I.Y. Pryhodko, P.V. Krot, Vibration monitoring system and the new methods of chatter early diagnostics for tandem mill control, International Conference “Vibration in Rolling Mills”, London, 2006, pp. 87-106.

[7] M.C. Valigi, S. Papini, Analysis of chattering phenomenon in industrial S6-high rolling mill, Diagnostyka 14 (2013) 3, 3-8.

[8] I.A. Kozhevnikova, N.L. Bolobanova, A.V. Kozhevnikov, Cold Rolling with Vibration of the Working Rollers, Steel in Translation 47 (2017) 11, 695-698.

[9] V.M. Sinitsky, Yu.V. Rybakov, Krutil’nye kolebaniya shpindelej i vibracii kletej stanov holodnoj prokatki s nezavisimym privodom rabochih valkov, Proizvodstvo Prokata (2004) 10, 23-26. (In Russian).

[10] M.R. Niroomand, M.R. Forouzan, M. Salimi, H. Shojaei, Experimental Investigations and ALE Finite Element Method Analysis of Chatter in Cold Strip Rolling, ISIJ International 52 (2012) 12, 2245-2253.

[11] Yu.D. Makarov, E.G. Beloglazov, I.V. Nedorezov, T.A. Mezrina, Issledovanie parametrov processa holodnoj prokatki pered nachalom vibracij na nepreryvnom stane, Stal (2008) 12, 92-95. (In Russian).

[12] V.A. Pimenov, O prichinah narusheniya ustojchivosti holodnoj prokatki, Izvestiya Vuzov. Chernaya metallurgiya (1990) 8, 36-38. (In Russian).

[13] N.G. Kolbasnikov, A.I. Demidov, Kavitaciya i razrushenie smazochno-ohlazhdayushchej zhidkosti – prichina vozniknovenij vibracij kletej stanov holodnoj prokatki i poyavleniya defekta «rebristost' polosy», Metalloobrabotka (2004) 2, 12-16. (In Russian).
[14] V.M. Sinitsky, Yu.V. Rybakov, Stal'naya polosa v mezhvalkovom prostranstve stana holodnoj prokatki kak kolebatel'naya struktura, Proizvodstvo Prokata (2002) 5, 18-20. (In Russian).
[15] E.A. Garber, V.P. Naumchenko, V.I. Abramenko, Issledovanie prichin obrazovaniya rebristosti na poverhnosti holodnokatanyh polos, Chernaya Metallurgiya Bulletin (2001) 1, 16-19. (In Russian).
[16] E.A. Garber, A.V. Kozhevnikov, V.P. Naumchenko, I.A. Shadrunova, S.I. Pavlov, Issledovanie, modelirovanie i ustranenie vibracij v rabochih kletyah stanov holodnoj prokatki, Proizvodstvo Prokata (2004) 6, 34-41. (In Russian).

List of symbols, abbreviations and acronyms

i – work stand number;
υ_i – rolling speed in the stand i;
h_i – strip thickness;
ε_i – individual percent reduction of the strip;
σ_i – strip tension;
V_i – strip volume per second rolled in stand i;
F_i – the cross sectional area of the strip at the exit from rolls of the stand i;
t – rolling time;
ΔV – the difference of steel volumes per second rolled in adjacent stands;
ΔV_{3-4} – the difference of steel volumes per second rolled in stands 3 and 4.

Note: Translated into English by Olga Mozdakova, Cherepovets, Russia.