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THE STUDY OF INFLUENCE OF WORK ROLLS VIBRATION DURING COLD ROLLING ON THE QUALITY OF STEEL STRIP SURFACE

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Preliminary Note – Prethodno priopćenje

The article represents the results of the study of work rolls vibration influence on the quality of cold rolled strips on the basis of computer simulation of the rolling process in the DEFORM-2D program. It was determined that the size of alternating shadow zones on the surface of cold rolled strips received through simulation complies with experimental data. The comparison of the strip surface profile change depending on work roll vibration frequency and rolling speed demonstrated that rolling speed increase leads to increase in width of transversal stripes, and increase of vibration frequency leads to their decrease. The results of computer simulation led to the conclusion that vertical vibration of work rolls as the oscillation curve according to the Harmonic Law does not significantly influence the longitudinal strip off gauge. It was found that work rolls horizontal vibration does not influence the nature of deviations in the strip surface profile. Recommendations on use of simulation results are provided to evaluate the strip surface profile.

Key words: steel strip, cold rolling, work rolls vibration, surface quality, computer simulation

INTRODUCTION

Provision of high strip surface quality indicators during cold rolling is one of priorities of flat rolled products manufacturing. At the same time, a wide range of these indicators including roughness parameters, ribbing, impurity and defects breaking surface continuity (for example, prints, scratches, marks, etc.) is identified.

One of the defects, which is difficult to remove and which occurs on the surface of cold rolled strips, is ribbing appearing as transversal zones with alternating dark and light shadows (Figure 1). The mechanism of origination of this defect on the surface of steel cold rolled strips is not yet fully understood, however, it is worth noting that papers [1 - 8] devoted to research of this defect origination and recommendations to reduce rejects because of this defect link it to chatter processes in work stands of continuous mills. Thus the reason of ribbing, according to authors of papers [1, 2], is self-vibration during rolling, in papers [3, 4] dynamic processes in equipment of main trains of work stands are named as the reason, in papers [5 - 7] it is a position of work rolls in a stand, and in paper [8] it is quality of rolls machining. Despite difference in the above-mentioned factors, it could ultimately be said that ribbing occurs under influence of oscillating processes of the roll assembly.

Considering special features of continuous cold rolling, it is difficult and mostly impossible to conduct experimental studies to identify influence of roll system oscillation on precision of strip dimensions and occurrence of surface defects on strips. Currently, in order to study the influence of work rolls vibration during cold rolling on process parameters and steel strip quality indicators, computing environments of finite element analysis are quite effectively applied. The paper [9] demonstrates the possibility to use a computing environment to study the influence of work roll vibration on strip thickness formation during cold rolling. The papers [10, 11] show the efficiency of numerical computer simulation of the cold rolling process during work rolls vibration. Therefore, it is highly relevant to continue studying the influence of work rolls vibration on strip elastoplastic deformation during cold rolling and its surface quality.

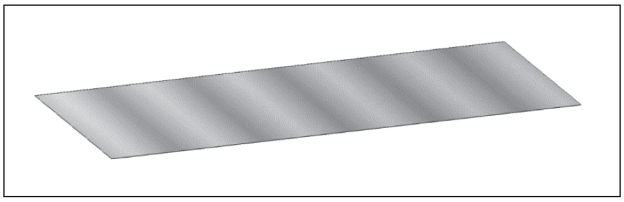

Figure 1 'Strip ribbing' surface defect

MODEL DESCRIPTION

In order to reveal the mechanism of defects occurrence on the surface of steel cold rolled strips during work rolls vibration, the finite element method implemented in the DEFORM-2D program was used. The 4th stand of the 5-stand mill 1700 of PAO Severstal was taken as the target of research, since the data collection system recorded the largest number of resonant vibra-

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tions in it leading to ribbing on the surface of cold rolled strips. The rolled strip was perceived as the elastoplastic environment having power-law hardening. The steel of 08ps (Rus. "08пс") grade was taken as the strip material. The strip dimensions were 300 mm in length and 0,7 mm in thickness. The strip model was created symmetrical in thickness. Work rolls with the diameter of 600 mm were taken as "hard surfaces" to decrease computational efforts and considering that rolls hardness is higher than strip hardness. The typical size of the finite element was taken to be 0,025 mm. The Coulomb friction model was used to describe the strip contact with a roll. There were considered relative reductions in the stand of 26 % and 33 %, and the rolling speed of 10 m/s, 15 m/s and 20 m/s. In addition to work roll rotation, their vertical vibration was set as the oscillation curve according to the Harmonic Law.

$$x = A\sin(\omega t+\varphi_0), \quad (1)$$

where x – the value describing the work roll position at t time against the equilibrium; A – the oscillation amplitude as the maximal body shift from the equilibrium position; $\omega = 2\pi/T$ – the cyclic frequency; T – the oscillation period; φ_0 – the initial phase.

The values of work rolls vertical movements and speeds at the moment of vibration were determined on the basis of results of full-scale experiments on operating cold rolling mills 2 030 and 1 700 [12, 13]. The maximal range of work roll vibration displacement was taken as 0,4 mm, and vibration frequency was taken as 100 Hz, 200 Hz, and 300 Hz. At the beginning of the rolling process, a boundary condition was established at the front end of the strip for strip grip by rolls: assemblies of the front end move in the direction of strip movement in accordance with the set rolling speed. Figure 2 provides the rolling model in an initial condition.

RESULTS AND DISCUSSION

Strip surface profile change depending on work roll vibration frequency and rolling speed was studied on the basis of the developed mathematical model. Figures 3 to 5 show strip surface profiles plotted for the length of 400 mm. When vibration is absent (Figure 3) the strip surface is smooth. Deviations provided on Figures 4 and 5 may be considered as the ribbing defect – alternating light and dark stripes on steel surface. In contrast

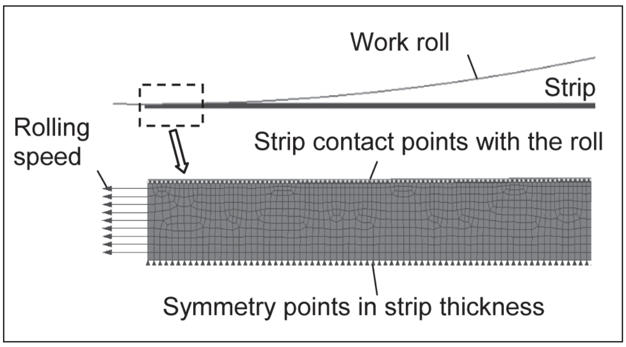

Figure 2 Model setting

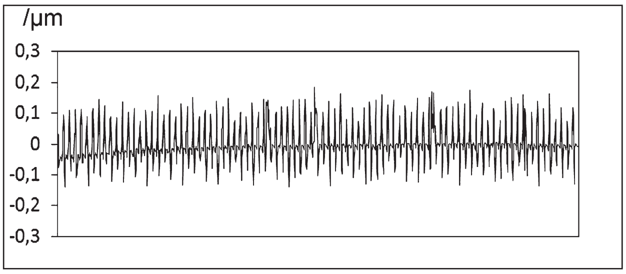

Figure 3 Strip surface profile without vibration

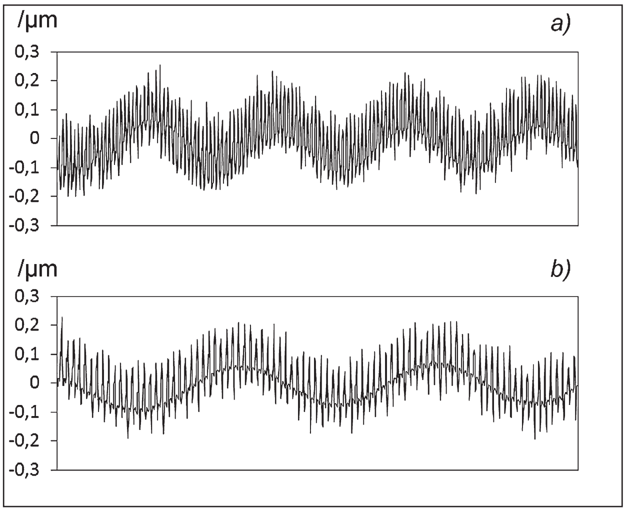

Figure 4 Strip surface profile at work roll vibration frequency of 100 Hz: a) υ = 10 m/s; b) υ = 15 m/s

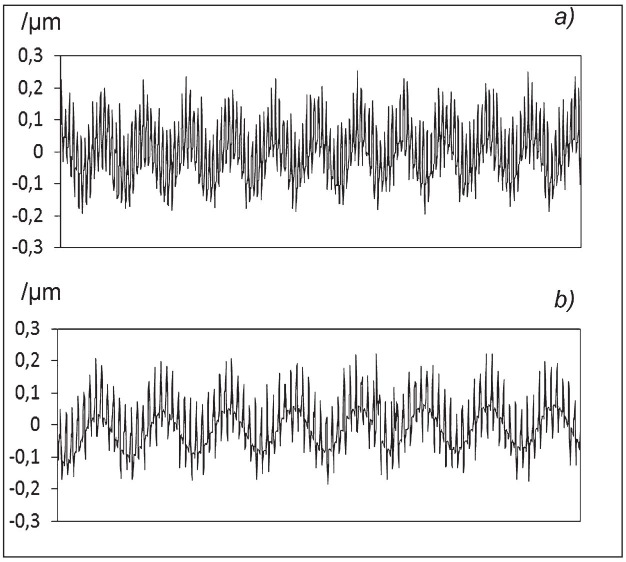

Figure 5 Strip surface profile at work roll vibration frequency of 300 Hz: a) υ = 10 m/s; b) υ = 15 m/s

to values of surface texture variation, the nature of deviations depends on the rolling speed and vibration frequency. Increase of the rolling speed leads to increase in width of transversal stripes, and increase of vibration frequency leads to their decrease.

Based on the results of the studies, graphs for dependency of sizes of transversal shadow stripes on rolling speed and work roll vibration frequency were plotted.

The cold rolled strip of 08ps steel grade with the thickness of 0,46 mm and the width of 915 mm, made according to the rolling mode with the total reduction of 77,5 % and actual speed of 15 m/s, carried out during a

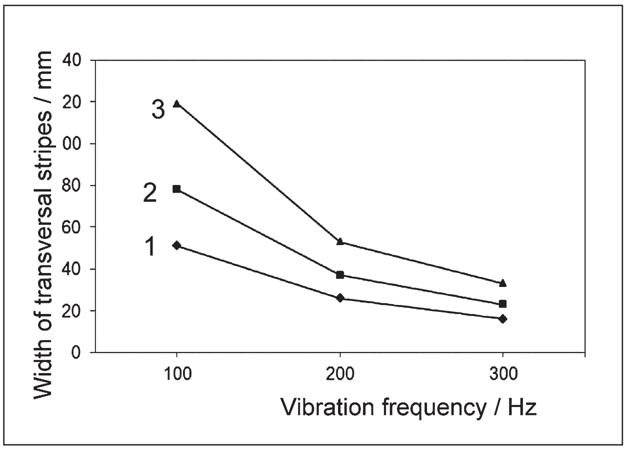

Figure 6 Dependence of the width of transversal stripes on vibration frequency and rolling speed: 1 – 10 m/s; 2 – 15 m/s; 3 – 20 m/s

full-scale experiment at mill 1700 of PAO Severstal with roll assembly vibration frequency change of 112 to 119 Hz [12], had periodical defects on the surface as shadow stripes with the width of 70 mm. Calculations made using the developed model demonstrated (curve 2 of Figure 6) that the width of alternating shadow zones was 70 to 68 mm indicating the model compliance with the actual object and target of the study.

The simulation demonstrated that increase of individual percent reduction in a stand from 26 % to 33 % results in increase of shadow stripes width by 8 % to 10 %, and set of horizontal vibration of work rolls as the oscillation curve according to the Harmonic Law (1) does not influence the nature of deviations of the strip surface profile.

The studies have shown that work rolls vibration itself does not significantly influence the longitudinal strip off gauge. Regardless of work rolls vibration frequency, the mean value of the strip thickness after rolling with reduction of 26 % was 0,52 mm, and after reduction of 33 % it was 0,47 mm. The thickness variation range in case of work rolls vibration and reduction increase did not exceed 1,5 μm, which provides precision of rolled strips with respect to off gauge.

CONCLUSION

The results of the research can be used when evaluating the “strip ribbing” defect and implementing actions on continuous cold rolling mills to prevent and eliminate this defect.

The influence of vibration frequency and rolling speed on alternating shadow zones was evaluated on the basis of plotted curves of change of the zones’ width.

The developed model of the cold rolling process and received results can be used for development of rolling modes providing stable operation of a continuous mill without resonant vibrations.

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List of symbols, abbreviations and acronyms

x – the value describing the work roll position at time against the equilibrium;
t – time;
A – the oscillation amplitude as the maximal body shift from the equilibrium position;
ω – the cyclic frequency;
T – the oscillation period;
φ_0 – the initial phase;
$\boldsymbol{v}$ – rolling speed.

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