ASSESSMENT OF MICROSTRUCTURAL CHANGES IN S325 HEAT-RESISTANT STEEL AFTER COLD ROLLING USING EDDY CURRENT TESTING

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1. Introduction

In the recent decade, the application of the eddy current method in the identification of microstructural changes spread significantly to automotive [1], aircraft [2] and heavy [3] industries. Such microstructural changes occurring in steel due to the cold rolling process have a significant impact on their mechanical properties since deformed material exhibits notable surface hardening. The presented work aimed to identify these microstructural changes represented by texture formation and subsequent increase of residual stress in S235 steel shee to further correlate them with non-destructive testing results. Stereological parameters were determined for the as-received material and after the cold rolling process. Subsequently, a comparison of the dislocation density for the initial and deformed materials was performed. The same surfaces were then subjected to eddy current measurements. The impedance trajectories obtained for various specimen surfaces with different levels of cold plastic deformation were analyzed. The obtained results exposed the dependence of the impedance phase angle on the residual stress level.

2. Methodology

S235 steel specimens with different degrees of deformation were used in this study. The initial specimen (S) was a 12 mm thick hot rolled sheet. It was then cold rolled into 8 mm and 6 mm thick sheets and designated as S1W and S2W, respectively.

Metallographic examinations and stereological analysis were performed using a NIKON light microscope. The crystallographic texture of the samples was determined using a Hitachi SU70 microscope with an EBSD attachment from HKL. Subsequent studies included the assessment of dislocation density based on TEM observations of thin foil samples obtained by electrolytic thinning [4]. The last stage involved the analysis of the eddy current signal on various surfaces of S235 steel specimens with various degrees of deformation. The impact of cold-work hardening on the value of the impedance phase angle was analyzed.

3. Results

The microstructure of rolled sheets exhibited a strong texture, which is visible in the cross-sectional view (Fig. 1). Its presence could be also confirmed based on the results of stereological tests, including a quantitative assessment of grain elongation.

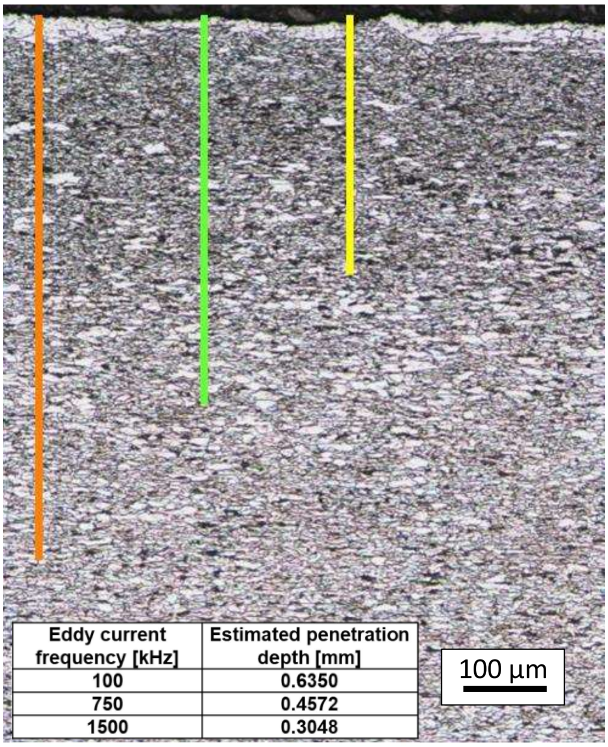

Fig. 1. Microstructure of the cross-section of the rolled sample S2 with estimated penetration depths of eddy currents for different induction frequencies.

Fig. 1 shows the estimated penetration depths of eddy currents for three values of the excitation frequency that were selected for testing. The impedance phase angle was measured on the surfaces of rolled specimens with different deformations and cross-sections in transverse and longitudinal directions to the rolling. It was observed, that the most notable differences were found for the lowest penetration depth (Fig.2). Such behaviour was related to the highest deformation degree of the surface due to cold-work hardening. The deeper the measurement frequency was, the lower differences were recorded. It was directly connected with the microstructural changes that occurred below the surface (Fig.1)

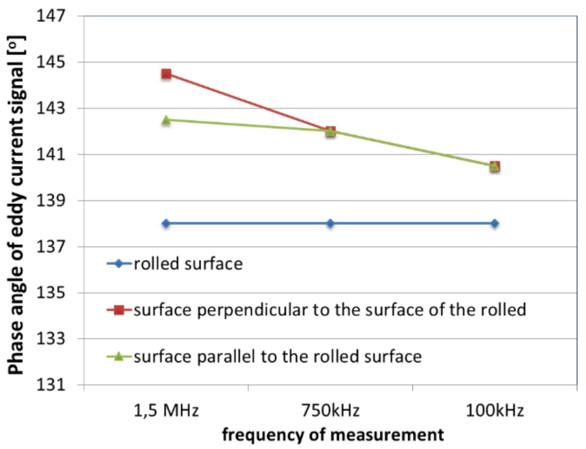

Fig. 2. Changes in the phase angle as a function of frequency for the three surfaces of the sheet with a thickness of 6mm.

The results of impedance measurements performed on surfaces with various degrees of deformation were compared with dislocation density measurement, as shown in Table 1. Such comparison clearly indicates the increase of dislocation density for specimens after cold rolling in comparison to the initial state. The higher the dislocation density was, the more material hardening was introduced.

Table 1. Mean value for dislocation density in specimen S, SW1, SW2

Specimen	Dislocation density
S (initial state, 12 mm thick)	$5.50 \times 10^{12} m^{-2}$
S1W (cold rolled, 8 mm thick)	$9.14 \times 10^{12} m^{-2}$
S2W (cold rolled, 6 mm thick)	$1.10 \times 10^{13} m^{-2}$

The dependence of the eddy current parameter on the dislocation density measured for samples at various degrees of deformation, with different penetration depths, was shown in Fig. 3. It could be observed, that the same deformation degree represented by the specific dislocation density value could be more precisely detected when higher measurement frequency is applied.

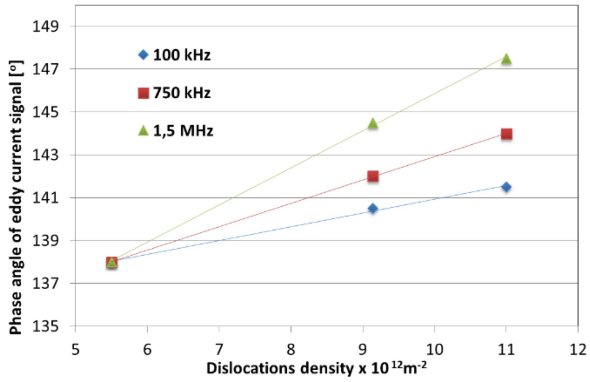

Fig. 3. The influence of dislocation density on the phase angle for different ET penetration depths.

4. Conclusions

In this paper, qualitative characteristics of microstructural changes in the S235 steel sheets during cold rolling were obtained. It was shown, that changes in the grain shape, size and elongation, crystallographic and morphological texture as well as dislocation density and surface residual stresses could be detected by using eddy current methodology. The elaborated methodology of non-destructive assessment of specimen residual stresses value can be applied i.e. for the evaluation of the quality of conducted surface mechanical treatment and for localization of microstructural notch.

References

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