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Analysis of deformation textures of asymmetrically rolled steel sheets

Sang Heon Lee, Dong Nyung Lee*

School of Materials Science and Engineering, Seoul National University, Seoul 151-742, South Korea

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Abstract

Asymmetric rolling has been studied to obtain the shear deformation texture of bcc steels through the thickness. Asymmetric rolling in which the circumferential velocities of two working rolls are different can be achieved by different roll radii at the same rotation rates, different roll speeds at the same roll radii and single roll drive. The deformation of steel sheets in the three different asymmetric rolling methods was analyzed by FEM. The deformation was used to calculate crystal rotation by full constraints Taylor model to predict the deformation textures. The texture evolution during the asymmetric rolling was measured and analyzed with the emphasis on the effect of shear reversions. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Asymmetric rolling; Shear deformation; Texture; FEM

1. Introduction

Asymmetric rolling is known to take place due to differences in the circumferential velocities of working rolls caused by lubrication mismatch, different angular speeds or different roll diameters. Because asymmetric rolling process can gain such merits as less rolling pressure distribution, rolling force, rolling torque and a very thin thickness with high rolling precision, it becomes more and more important in the recent years. In the previous investigation, both experimental and numerical approaches have been performed [1–4]. But, few attempts have been made to utilize the asymmetric rolling from the viewpoint of deformation texture.

In aluminum alloys with fcc crystal structure, ND//$\langle 1\,1\,1 \rangle$ component in the shear deformation texture can improve the plastic strain ratios. The orientation component forms in the surface layer at the high friction between the sheet and rolls and is influenced by a geometric parameter

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* Corresponding author. Fax: +82-2-885-9761.

E-mail address: dnlee@snu.ac.kr (D.N. Lee).

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Nomenclature

$\dot{\Omega}_{ij}$	the lattice rotation rates
$\varphi_1, \Phi, \varphi_2$	the Euler angles
$\dot{\varphi}_1, \dot{\Phi}, \dot{\varphi}_2$	time derivatives of the Euler angles
$\dot{d}_{ij}$	the velocity gradient
m^s_{ij}	the Schmid factor
$\dot{\gamma}^s$	the shear rate
μ	Coulomb's friction coefficient

defined by the ratio of the mean thickness of the sheet to the contact length between the sheet and rolls [5,6].

Lee et al. [7–13] suggested asymmetric rolling with different roll diameters for introducing the shear deformation through the thickness of aluminum sheets, which in turn gave rise to shear deformation textures consisting of $\{1\,1\,1\}\langle 1\,1\,0\rangle$, $\{1\,1\,2\}\langle 1\,1\,0\rangle$, and $\{0\,0\,1\}\langle 1\,1\,0\rangle$ and hence higher plastic strain ratios. Sakai et al. [14] suggested single roll drive rolling of aluminum sheets, by which high *r*-values were obtained. Single roll drive rolling was achieved by one roll driven by a motor and the other roll disconnected from the driving shaft.

For grain-oriented silicon steel with bcc crystal structure, Liu et al. [15] studied asymmetric rolling. But, their concern was to produce thin gauge sheets. Dunn et al. [16] found that $\{1\,1\,0\}\langle 0\,0\,1\rangle$ single crystal of silicon steel formed to the $\{1\,1\,1\}\langle 1\,1\,2\rangle$ orientation when plane strain rolled and the original orientation of $\{1\,1\,0\}\langle 0\,0\,1\rangle$ was recovered after the rolled specimens was recrystallized. Ushioda et al. [17] reported similar result in a study on the 3% Si–Fe $(1\,1\,1)[1\,1\,2]$ single crystal. Bottcher et al. [18] explained the result by the fact that growth rate is fast for an orientation relationship of about 27° around a common $\langle 1\,1\,0\rangle$-axis between a growing nucleus and the deformed matrix. Lee et al. [19] explained this phenomenon by the energy release maximization theory.

In this paper, the deformation and texture of bcc sheets due to asymmetric rolling were measured and analyzed for a possible application of asymmetric rolling to the fabrication of grain-oriented silicon steel.

2. Computational procedure

The deformation of the rolled material was calculated by a finite strain, elasto-plastic program [20]. The friction coefficient between the sheet and rolls was assumed to be 0.3. It is a typical value in the high-temperature rolling [21]. The flow curve at 700°C used for FEM is shown in Fig. 1. Young's modulus of the material was 100 GPa. A temperature change during rolling was ignored. The crystal rotation was calculated using the strain histories obtained by FEM analysis. This decoupled method was shown to work well for high-symmetry crystals like fcc and bcc crystals [23]. Both $\{1\,1\,2\}\langle 1\,1\,1\rangle$ and $\{1\,1\,0\}\langle 1\,1\,1\rangle$ slip systems were employed. The full constraints Taylor model by linear programming was applied to the crystal rotation to calculate