Shape Control of Alloy Steel Rolled by Sendzimir Mill

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In order to improve quarter waves occurred in the wide and thin gauged alloy steel rolled by 20-high sendzimir mill, a computer simulation based on the divided element method and an actual cold rolling experiment were carried out. Quarter waves were simulated by elastic deformation analysis of rolls considering bending deformation of back up rolls and the effect of control actuators on controllability of quarter waves were analyzed. Computer simulation showed that control actuators such as shifting of the 1st intermediate roll and crown adjustment of As-U-Roll in back up rolls were not effective to control quarter waves and that changing taper mode (both length and magnitude) at the barrel-end taper radius of the 1st intermediate roll was rather very effective. From an actual rolling experiment it was verified that quarter waves could be reduced remarkably by changing taper mode of the 1st intermediate roll.

Key Words: Sendzimir Mill, Shape Control, Quarter Wave, Shifting, Taper, 1st Intermediate Roll (IMR), As-U-Roll

1. Introduction

Sendzimir mill is widely used for rolling hard materials such as stainless, silicon and alloy steels. It is composed of small diameter of work rolls for reducing rolling load and many rolls for backing up the work rolls. As shape control actuators, there are shifting of the 1st intermediate roll (IMR) in the width direction of strip, taper mode (length and magnitude) of the 1st IMR and crown adjustment of As-U-Roll in back up rolls (BUR). But since sendzimir mill has small diameter of work rolls in comparison with 4-high and 6-high mills, quarter waves are occurred at quarter part of strip by complex elastic deformations of work rolls. It results in a large obstacle of shape quality and productivity.

Generally, design for taper mode of the 1st IMR has been considered as the most effective method to control strip shape and it has been determined by experience and experiments. However, taper mode of the 1st IMR currently used is not sufficient to control quarter waves occurred by various rolling conditions. Therefore, an analytic approach to shape analysis of sendzimir mill in order to optimal taper mode of the 1st IMR is necessary. Hattori (1984), Mizuta (1987) and Matsuda (1987) have been studied for elastic deformation analysis of rolls of sendzimir mill based on the divided element model by assuming BUR to be rigid body or considering bending of BUR. But little study of reducing quarter waves has been done until now and although Hara (1991) has suggested a concave mode of the 1st IMR, it is not pratical because of accuracy of roll grinding.

In this paper, quarter waves were simulated by roll deformation analysis of sendzimir mill considering bending deformation of BUR and the effect of control actuators of sendzimir mill on controllability of quarter waves were analyzed and then an effective method to reduce quarter waves was accomplished. Finally, the effect of the developed method was verified by an actual rolling experiment.
2. Method of Solution

2.1 Elastic deformation analysis

2.1.1 Modelling

The roll arrangement of sendzimir mill is shown in Fig. 1 and the divided element method suggested by Shohet and Boyce (1968) was applied for elastic deformation analysis of rolls. The assumptions used for analysis were as follows:

a. Rolling is symmetric with respect to x- and y-axis so that only quarter part of the system needs to be analyzed.

b. Tension distribution in the width direction is constant.

c. Contact angles in the width direction between rolls are constant.

d. Contact pressure at each divided element is constant.

The divided number in the width direction of rolls was $m$ and the deformation of As-U-Roll was given compulsorily at each saddle position as shown in Fig. 2.

(1) Equilibrium equations

As shown in Fig. 3, the $N$th roll applied by $q$ numbers of distributed loads was considered. IF $P_{y}^{N}(j)$ and $P_{x}^{N}(j)$ are sums of x- and y-direction forces applied at the $N$th roll, respectively, they can be written as follows.

$$P_{y}^{N}(j) = \sum_{k=1}^{q} [\sin \theta_k \cdot P_{y}^{N}(j)]$$ (2)

where, $j$ and $\theta_k$ indicate divided element index and contact angle, respectively.

Equilibrium equations of forces for the $N$th roll (roll (1), (2), (3) and (4))

$$\sum_{j=1}^{m} [P_{y}^{N}(j) \cdot \Delta W(j)] = 0$$ (3)

$$\sum_{j=1}^{m} [P_{x}^{N}(j) \cdot \Delta W(j)] = 0$$ (4)

where, $\Delta W(j)$ is divided element length.

Equilibrium equations of moments for the $N$th roll (roll (5), (6), (7) and (8))

$$\sum_{j=1}^{m} [P_{y}^{N}(j) \cdot \Delta W(j) \cdot \frac{UL(j)}{RL}] = 0$$ (5)

$$\sum_{j=1}^{m} [P_{x}^{N}(j) \cdot \Delta W(j) \cdot \frac{UL(j)}{RL}] = 0$$ (6)

Fig. 1 Roll arrangement of sendzimir mill

Fig. 2 Analysis model of roll deflection based on divided element method

Fig. 3 Force equilibrium of roll