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A Numerical Study on the 2-D Temperature Distribution of the Strip on Run-Out Table of the Hot Mill

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Abstract. The cooling of steels on the run out table (ROT) has become a common practice in the production of hot rolled products. Therefore, the control of the cooling of the strip on ROT is an important issue in the strip steel production. Most of the researches performed at this moment deals with the simplified model and/or 1-D model. In this study, temperature distribution along the transverse direction has been investigated using the information collected from the onsite 1-D CTC log data. The simulator has been developed to predict temperature uniformity and to control the cooling rates of the strip. Several parameters such as correction factor and on/off density are optimized to calculate accurate cooling rate of the strip.

Keywords: Run-out Table, Hot strip mill, 2-D heat transfer, Strip segment, coiling temperature control (CTC).

1 Introduction

A run-out table (ROT) in hot strip rolling process located between the last finishing mill and the down coiler. The strip has to be cooled down to prescribed temperature when it passes through ROT. Because of the quality of the steel is strongly dependent upon the temperature distribution of the strip, the control of the cooling of the strip on ROT is an important issue in the strip steel production.

Cho *et al.* [1] presented numerical simulation for the flow pattern and free surface arising from multiple water jets impinging on a moving surface on ROT. Specially, the effects of surface width and increasing flow rate have been investigated. Sun *et al.* [2] presented an integrated process model for the analysis of thermal behavior of the strip occurring on ROT. They emphasized that the proposed model may serve as an effective tool for optimizing the diverse process parameters associated with cooling on ROT in hot strip rolling. Gadala and Xu investigated the cooling process of steel strip on the ROT using 2-D modeling [3]. Both transverse and longitudinal modeling is conducted, and the results of these simulations are discussed. Kumar and Sinha [4] developed a new model for the cooling process on the run out table of hot strip mills. The suitability of different numerical methods for the solution of the proposed model equation from the point of view accuracy and computation times is studied. Peregrina *et al.* [5]

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established that the thermal drop on ROT has a significant effect on flatness, at the edges in particular. The edge masking technology has been selected to control the temperature at the edge of the strip.

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2 ROT Model and Cooling Mechanism

Fig.1 shows schematically a ROT model of typical hot strip mill. The ROT consists of 16 water banks with 16 nozzles/ bank for laminar cooling on the top surface of the strip. Each bank also has 8 nozzles for spray cooling for spray cooling on the bottom surface of the strip. The cooling temperature profile along the ROT can be controlled by adjusting the strip speed, on/off status of nozzle and water temperature so on. In general, control factors including the on/off status of bank/nozzle are coded in program embedded in CTC (control temperature code).

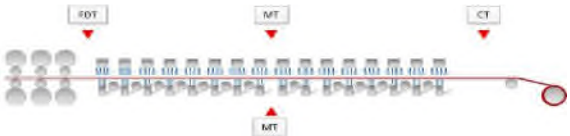

Fig. 1. A ROT model of typical hot strip mill

3 Two Dimensional Transverse Modeling

The cooling process on the ROT has been modeled as a two dimensional heat conduction equation written in the following form [6]:

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\dot{q}}{k} = \frac{1}{\alpha}\frac{\partial T}{\partial t} \quad (1)$$

Where the thermal conductivity, T is the temperature, is the heat generation per unit volume, $\alpha = k/\rho C_p$ is the thermal diffusivity.

The temperature measured at finishing delivery (FDT) considered as initial temperature of the transient heat transfer problem. Boundary conditions at the external surfaces of the strip are convection and radiation boundary conditions written in the following form [6]: The finite difference formulation for the governing equation of (1) and boundary conditions has been carried out by the control volume approach [6].

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4 Results and Discussion

Fig. 2 illustrates the temperature variations due to the water cooing through the banks along the ROT. The strip surface temperature passing through the bank #1 – bank #3 decreases steeply and recovers its temperature at bank #4 due to the heat conducted in from the inside of the strip. The 2nd temperature drops occurs due to the cooling at fine bank #16 at the end of ROT. The experimental temperature variations collected from the CTC log file is also plotted in this figure. It shows that the calculated temperature agrees well with CTC data within 3.6 % of error bound. Temperature variation for the other strip (coil A) with thinner thickness is also plotted in this figure. It is noted that the temperature differences between surface and average temperature becomes small as the thickness decreases. It is also shown that the temperature of the strip is large compared to that of coil C.

The CTC log file provides only the cooling information of centerline of the strip. In this study, the heat transfer coefficient along the width direction (h_w) is to be developed by using the HTC that is already predicted at the center of the strip (h_c). Fig. 3 shows the temperature distribution along the width direction at the FD and coiling temperature (CT) measured at the coiler entry. The temperature near the edge of strip decreases significantly due to the heat loss at the side surface. This non-uniform temperature distribution attenuated at the end of cooling process along the ROT (CT). The HTC ratio (h_w / h_c) developed in this study illustrates is also plotted in this figure. HTC ratio varies from 1 to 0.74 near edge (18% of width). It can be seen that the CT calculated by using simulated HTC coincides well with measured CT within error of 1%.

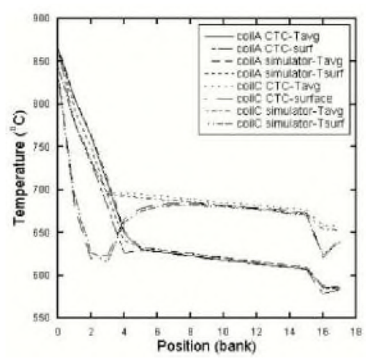

Fig.2. Temperature variations along the strip on ROT

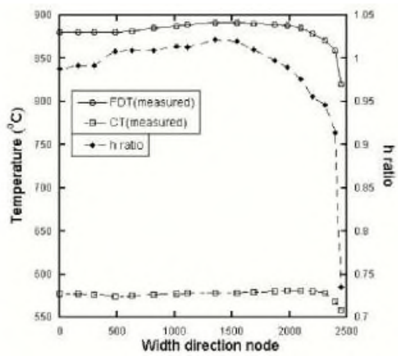

Fig. 3. Temperature and HTC distribution across the width direction

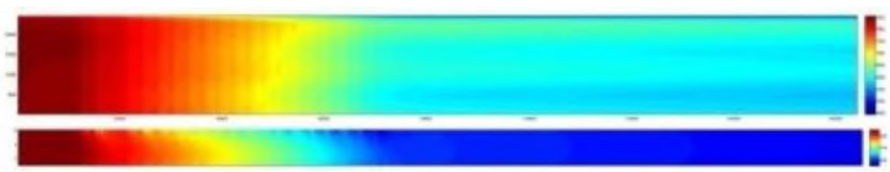

Fig. 4. 2-D Temperature variations along the strip on ROT.

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Fig. 4 illustrates the temperature contours of width and thickness direction. It is noted that the temperature of the strip is almost uniform after water cooling in this relatively thin strip. It can be seen that the temperature per each head is not big because of increased strip velocity (short cooling time). The bottom surface temperature decreases almost linearly due to the uniform HTC without water jet interferences like top surface.

5 Conclusion

2-D numerical analysis has been performed to simulate the cooling process on ROT of a hot strip. Various factors that affect the temperature of a strip such as heat transfer coefficient, impinging jet cooling and variation of thermal property with temperature. The heat transfer coefficient representing the water cooling effect from the impinging jet was investigated to predict the temperature of the strip. It shows that the calculated temperature agrees well with CTC data within 3.6 % of error bound. The HTC ratio (h_w / h_c) was also developed to calculated transverse temperature distribution of the strip. The HTC ratio varies from 1 to 0.74 near edge (18% of width) results in the temperature variation along the width direction.

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