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Optimization of Temperature and Force Adaptation Algorithm in Hot Strip Mill

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Abstract: In the hot strip rolling control system, the temperature distribution and deformation resistance are the main parameters affecting prediction of rolling force. In order to improve the model prediction precision, an optimization algorithm based on objective function was put forward, in which the penalty function index was adopted. During the adaptation process, the temperature distribution and deformation resistance were taken as the optimized parameters, and the Nelder-Mead simplex algorithm was used to search the optimal solution of the objective function. Furthermore, the temperature adaptation and force adaptation were solved simultaneously. Application results show that the method can improve the accuracy of the rolling force model obviously, and it can meet the demand of the industrial production and has a good application prospect.

Key words: hot strip mill; adaptation; temperature distribution; force prediction; objective function; simplex algorithm

In the tandem hot rolling process, the prediction precisions of the temperature model and rolling force model are the main factors influencing the product quality. In order to match the delivery side temperature, applications of mathematical models[1], FDM (finite difference method)[2,3], FEM (finite element method)[4], and zonal compensation method[5] to the temperature calculation have proliferated, and based on these models, the rolling force adaptation was carried out. Because of the coupled relationship between the temperature and rolling force, the prediction error of temperature adaptation can influence the rolling force adaptation, and the prediction precisions of the temperature and the rolling force are influenced by each other, so it is difficult to treat them individually.

In this paper, aiming at the above problem, an adaptation method with objective function was designed. Through solving objective function, the temperature distribution coefficient and force adaptation coefficient were received simultaneously. Practical applications show that the adaptation algorithm can enhance the force and temperature precision, and the prediction of temperature and rolling force achieved good effect.

1 Finishing Mill Arrangement

Fig. 1 shows the arrangement of a typical tandem hot mill. The main equipments are tandem stands and two pyrometers which are located at the entrance and delivery sides of the finishing zone. The high-pressure descaling water is used at the entrance side, and the inter-stand spray water is adopted between the neighboring stands.

The control unit in the control system contains a stand unit and a cooling unit, and the pyrometer in

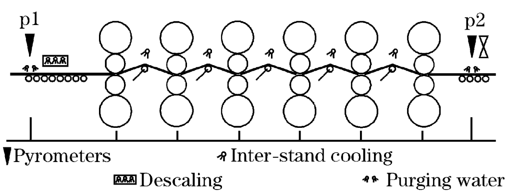

Fig. 1 Arrangement of tandem hot mill rolling line and control unit

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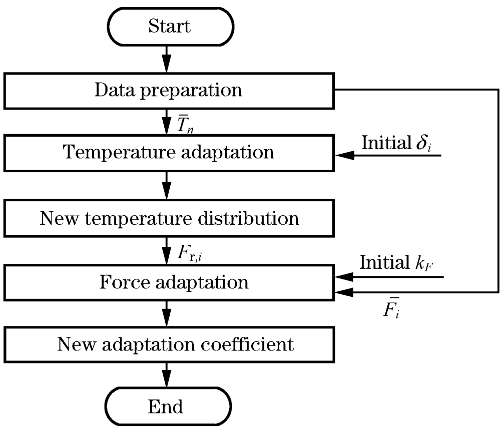
the delivery side (p2 in Fig. 1) is taken as a virtual stand unit, the cooling part of which is the purging water. The process of model calculation is carried out based on the control unit, which is repeated for each unit in turn.

2 Traditional Adaptation Models

The target of the temperature adaptation is to approach the actual finishing delivery side temperature. With the temperature distribution coefficient δ_i, the temperature error ΔT_e from the predicted value T_n and the mean of actual pyrometer values $\overline{T}_n$ and the initial deformation resistance coefficient k_F, the rolling force is repredicted to finish the force adaptation. The traditional adaptation models are introduced in the following sections. The adaptation scheme is shown in Fig. 2.



$F_{r,i}$—Repredicted force of stand i; $\overline{F}_i$—Measured force of stand i.

Fig. 2 Traditional adaptation scheme

2.1 Temperature adaptation model

When the strip head reached the delivery side pyrometer, the temperature error can be obtained through the predicted temperature and the actually measured temperature. In order to approach the delivery side temperature for the next coil, a temperature compensation item was added to the compensation temperature model.

The repredicted temperature of each unit is expressed as:

$$T_n = T_0 + \sum_{i=1}^{n}[(\Delta T_A + \Delta T_W + \Delta T_f + \Delta T_c + \Delta T_d)_i + \delta_i \cdot \Delta T_e] \quad (1)$$

where

$$\Delta T_e = \alpha \cdot \Delta T_e' + (1-\alpha) \cdot (\overline{T}_n - T_n) \quad (2)$$

T_0 is the finishing mill entrance temperature, ℃; ΔT_A is the temperature reduction by air cooling, ℃; ΔT_W is the temperature reduction by water cooling, ℃; ΔT_c is the temperature reduction by conductivity, ℃; ΔT_d is the temperature increase by deformation, ℃; ΔT_f is the temperature increase by friction, ℃; $\Delta T_e'$ is the temperature error of the previous coil, ℃; and α is the smooth coefficient, $0<\alpha<1.0$.

From the specified initial temperature at the entrance of the mill, the temperature of each unit can be obtained in the following two steps, which are repeated for each stand in turn:

(1) One-dimensional analysis of heat transfer due to the radiation and convection with air and cooling water as the strip travels from the entrance to the roll-gap exit zone to the next stand or, in the case of the last stand, to the delivery side;

(2) Roll-gap heat transfer analysis, taking into account the frictional heat generation, heat of deformation and conduction losses to the work rolls, in which the rolling force is predicted by the roll-gap temperature.

2.2 Force adaptation model

Based on the new temperature distribution from the temperature adaptation model, the temperature of each stand can be known; with the actual entrance and exit thicknesses of each stand from the rule of volume constancy[6-8], and the actual work roll velocity, the deformation rate $\dot{\varepsilon}$ can be calculated, so the repredicted rolling force F can be expressed as

$$F = k_F \cdot 1.15 \cdot \sigma_s(T, \dot{\varepsilon}) \cdot l_c \cdot w \cdot Q_p \quad (3)$$

where, σ_s is the deformation resistance, kN/mm^2; T is the predicted temperature at the roll bite, ℃; l_c is the contact arc length, mm; w is the width, mm; and Q_p is the influential coefficient in stressed state.

In the rolling force model, the deformation resistance was the main adaptation parameter, and the adaptation coefficient is expressed as

$$k_F = \beta \cdot k_F' + (1-\beta) \cdot \frac{\overline{F}}{F'} \quad (4)$$

where, k_F' is the adaptation coefficient of the previous coil; F' is the repredicted rolling force with the new deformation resistance $\sigma_s(T, \dot{\varepsilon})$; $\overline{F}$ is the mean value of actual rolling force; and β is the smooth coefficient, $0<\beta<1.0$.

2.3 Adaptation sub-models

The sub-models are called the temperature and the force adaptation models. The heat transfer models in non-deforming zone are divided into the air cooling temperature model and the water cooling