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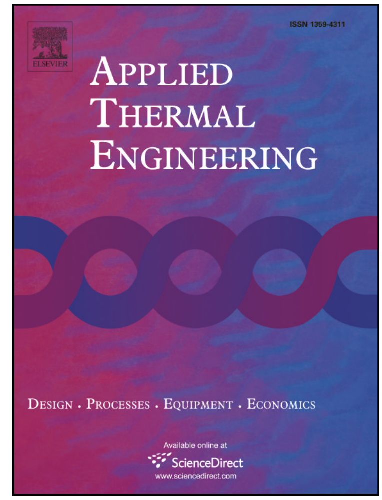

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Nonlinear dynamic simulation and control of large-scale reheating furnace operations using a zone method based model

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Abstract

Modern reheating furnaces are complex nonlinear dynamic systems having heat transfer performances which may be greatly influenced by operating conditions such as stock material properties, furnace scheduling and throughput rate. Commonly, each furnace is equipped with a tailored model predictive control system to ensure consistent heated product quality such as final discharge temperature and temperature uniformity within the stock pieces. Those furnace models normally perform well for a designed operating condition but cannot usually cope with a variety of transient furnace operations such as non-uniform batch scheduling and production delay from downstream processes. Under these conditions, manual interventions that rely on past experience are often used to assist the process until the next stable furnace operation has been attained. Therefore, more advanced furnace control systems are useful to meet the challenge of adapting to those circumstances whilst also being able to predict the dynamic thermal behaviour of the furnace. In view of the above, this paper describes in detail an episode of actual transient furnace operation, and demonstrates a nonlinear dynamic simulation of this furnace operation using a zone method based model with a self-adapting predictive control scheme. The proposed furnace model was found to be capable of dynamically responding to the changes that occurred in the furnace operation, achieving about ±10 °C discrepancies with respect to measured discharge temperature, and the self-adapting predictive control scheme is shown to outperform the existing scheme used for furnace control in terms of stability and fuel consumption (fuel saving of about 6%).

Keywords: zone method; reheating furnace; hybrid model; nonlinear dynamic simulation; self-adapting predictive control

1. Introduction

In every hot-rolling operation, the reheating furnace is a critical component determining quality of end-product: steel blooms, billets or slabs (known as stock). Therefore, most reheating processes require precise control of the stock temperature and temperature uniformity over the entire heating period. Whilst energy consumption in a reheating furnace depends greatly on production conditions such as stock dimension, material grade and throughput, improved control of the furnace firing pattern can lead to indirect energy saving through improving the furnace set-point temperatures. However, the multi-zone cascaded construction of reheating furnaces and the associated thermal inertia of the furnace make the task of furnace temperature control very challenging, particularly on occasions of changes in,

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