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# Parameter optimization through performance analysis of model based control of a batch heat treatment furnace with low $NO_x$ radiant tube burner

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**Abstract**

A model based control structure for heat treating a 0.5% C steel slab in a batch furnace with low $NO_x$ radiant tube burner is designed and tested for performance to yield optimal parameter values using the model developed in the companion paper. Combustion is considered in a highly preheated and product gas diluted mode. Controlled combustion with a proposed arrangement for preheating and diluting the air by recirculating the exhaust gas that can be retrofitted with an existing burner yields satisfactory performance and emission characteristics. Finally, the effect of variable property considerations are presented and critically analyzed.


*Keywords:* Batch furnace; Radiant tube burner; $NO_x$ minimization; Model based control; Parameter optimization

## 1. Introduction

Exercising proper control on heat generation and heat transfer is an important issue in many appliances like heat exchangers and combustion devices. A gas fired heat treatment furnace

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**Nomenclature**

| | |
|---|---|
| $A$ | area ($m^2$) |
| $C_p$ | specific heat (J/kg K) |
| CFHE | counter-flow heat exchanger |
| $e$ | error signal to PI controller for CFHE |
| $F$ | fraction of flue gas recirculated with fresh reactants |
| $K$ | gain constant |
| $\dot{m}$ | mass flow rate (kg/s) |
| $Q$ | heat transfer rate in CFHE (W) |
| $T$ | temperature (K) |
| $T$ | time (s) |
| $\varepsilon$ | effectiveness of CFHE |

*Subscripts*

| | |
|---|---|
| Air | incoming fresh air |
| C | cold stream of CFHE |
| D | desired condition |
| flue | flue gas |
| h | hot stream of CFHE |
| i | inlet condition of CFHE |
| I | integral control |
| M1 | first mixing chamber as shown in Fig. 4a |
| M2 | second mixing chamber as shown in Fig. 4a |
| max | maximum |
| min | minimum |
| o | outlet condition of CFHE |
| p | constant pressure |
| P | proportional control |
| $\Delta t$ | time step |

*Superscript*

| | |
|---|---|
| T | time |

involves both combustion and heat transfer. In combustion, the chemical energy of the reactants is released, and by heat transfer, the material, or load, being heat treated is carried through an appropriate temperature variation. Most of the prevalent control structures emerged from working knowledge of the input-output variations of the core processes. A model based control in which the process model evolves from the mechanistic approach provides an attractive alternative to prevailing control practices. This is because both economization and optimization studies of the performance can be undertaken prior to actual control implementation. Some researchers have already investigated process modeling of heat treatment furnaces [1–5] or one of their