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DEVELOPMENT MODEL OF AN ADAPTIVE CONTROL SYSTEM FOR REHEATING FURNACE

The influence of basic factors and parameters during heating control of continuous reheating furnace has been analyzed. The indispensability of restructuring operating system for automatic control temperature modes of furnace has been shown.

Keywords: continuous reheating furnace, parameters, control, system, heat transfer, model, quality.

Introduction

The slab heating process is one temperature control slab heating process which is applied widely in the industry. Errors of heating, which arise up at heating of metal, result in the decline of high-quality product output. Control of parameters by thermal process has great importance at automation both for economic work of furnace and for the high-quality heating of metal.

Adaptive control theory is the incorporation of parameter estimation in order to adapt to the control scheme to maintain performance despite changes in process parameters.

Use a PID controller from a new direction with the incorporation of a bottom temperature reading. There is a strong relationship between slab quality and the stability of the bottom temperature of the furnace [2].

Aim of study and research

The slab reheating processes use the reheating furnace which control temperature of the process about 1200 Celsius and consume time about 2-3 hours. Temperature of each zones are different according to function. As factors are temperature of gas and air, pressure of gas, general expense of fuel on furnace, time of heating of metal, productivity of furnace. As parameters are temperature of metal, overfull of temperatures on the section of slabs, temperature of combustion gases. Air-fuel ratios are controlled by open-loop ratio controllers sensing either pressure in the combustion air manifold, flow rate of fuel, or mechanical position of a pipeline valve. The manual of the furnace [1] describe the process of the furnace that using the thermal energy to furnace by burner which using double cross limit method adjust the ratio of air and fuel. The heating burners are the feedback control system. The air fuel ratio control of reheating furnace is feedback control which use PID controller. These control systems monitor either a single sensor or multiple sensors and adjust the fuel flow based on a predetermined relationship between inputs and outputs.

The problems in the present are reducing production cost and increasing performance in energy consumption which most cost of the factory from in the slab reheating process (fig. 1).

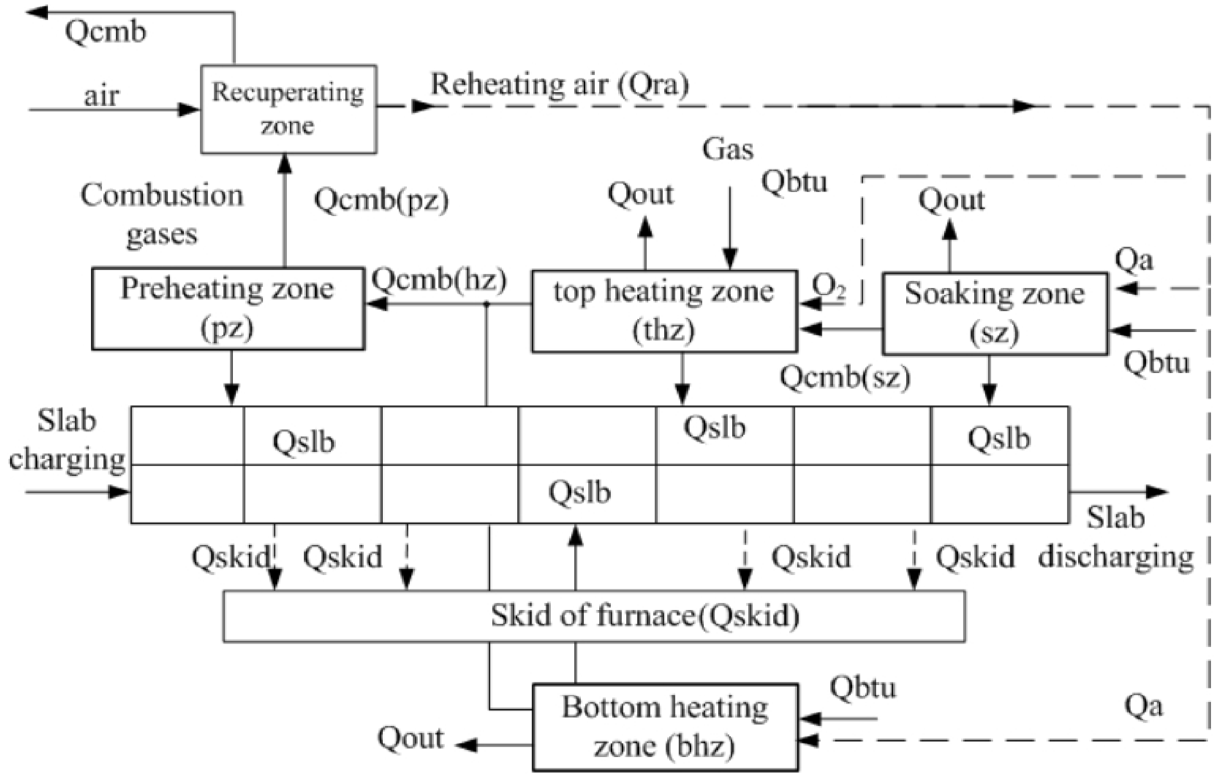

Fig. 1. – Heat balance of reheating furnace

The equation for heat transfer by radiation has the form:

$$Q = \sigma \cdot \varepsilon \cdot A_{SF} \cdot (T_{amb}^4 - T_{slb}^4), \quad (1)$$

where Q - heat transfer; σ - Stephan-Boltzmann constant, $5{,}67 \cdot 10^{-8}\ W / K^4 m^2$; A_{SF} − shape factor coefficient.

This equation can be linearized by using a mean operation temperature:

$$\dot{Q} = 4 \cdot \sigma \cdot \varepsilon \cdot A_{SF} \cdot \overline{T}^3 (T_{amb} - T_{slb}), \quad (2)$$

Then finding a generalized heat transfer resistance R:

$$\dot{Q} = \frac{A_{SF}}{R} \cdot (T_{amb} - T_{slb}), \quad (3)$$

The energy balance for the volume of combustion gas in soaking zone is shown below:

$$Ccmb_{k1} \cdot \frac{dTcmb_{k1}}{d\tau} = \dot{Q}cmb_{k1}, \tag{4}$$

$$Ccmb_{k1} \cdot \frac{dTcmb_{k1}}{d\tau} = \dot{Q}skid_{k1} + \dot{Q}cmb_{k2} + \dot{Q}slb_{k3} + \dot{Q}slb_{k4} + \dot{Q}out, \tag{5}$$

$$\begin{aligned} Ccmb_{k1} \cdot \frac{dTcmb_{k1}}{d\tau} &= \frac{Askid_{k1}}{Rskid_{k1}} \cdot (Tcmb_{k1} - Tskid_{k1}) + \frac{Acmb_{k2}}{Rcmb_{k2}} \cdot (Tcmb_{k1} - \\ &- Tcmb_{k2}) + \frac{A_{OF} \cdot Aslb_{k3}}{Rslb_{k3}} \cdot (Tcmb_{k1} - Tslb_{k3}) + \frac{A_{SF} \cdot Aslb_{k4}}{Rslb_{k4}} \cdot (Tcmb_{k1} - \\ &- Tslb_{k4}) + \dot{Q}out \end{aligned} \tag{6}$$

where A_{OF} − the absorption factor based on opacity; $\frac{dTcmb_{k1}}{d\tau}$ - time rate of change of the temperature of the combustion gases.

Experimental and simulation results

Adaptive control has been added recently to PID controllers to provide more flexibility. These systems are better able to adjust to the dynamic changes within the reheating furnace system through the incorporation of parameter estimation. They usually incorporate multiple PID controllers working together to monitor several parameters such as fuel flow, temperature of slabs, refractory temperatures, furnace pressure, and stack gas temperatures.

The mathematical simulation requires building of exact the mathematical model of process to adaptation on furnace. A simulation of heating processes is component part of general task of construction the automated system for the control temperature modes. The basic setting of model consists to providing the system by information about the temperature of billets in present moment and about the possible trajectory of heating [5]. Using Matlab and Simulink, a model can be created for simulation.

The system which control air to fuel ratio of 10:1 is the closed-loop system using PID controller. In the condition at flow rate in each zone is 600 m^3/h, the air temperature is 250 and the fuel is 50 Celsius. The method of open-loop identification via parameter estimation technique can be estimated the mathematical model of slab reheating furnace with measuring temperature in heating curve up process [6].

The formal equations are shown below:

$$\begin{aligned} \dot{X} &= AX + BU \\ Y &= CX + DU \end{aligned} \tag{7}$$

where A – is the state matrix; B - the input matrix ($Tamb, flow\ rate of\ gas and air$); C - the output matrix ($Tcmb, Tslb, Tamb.$).

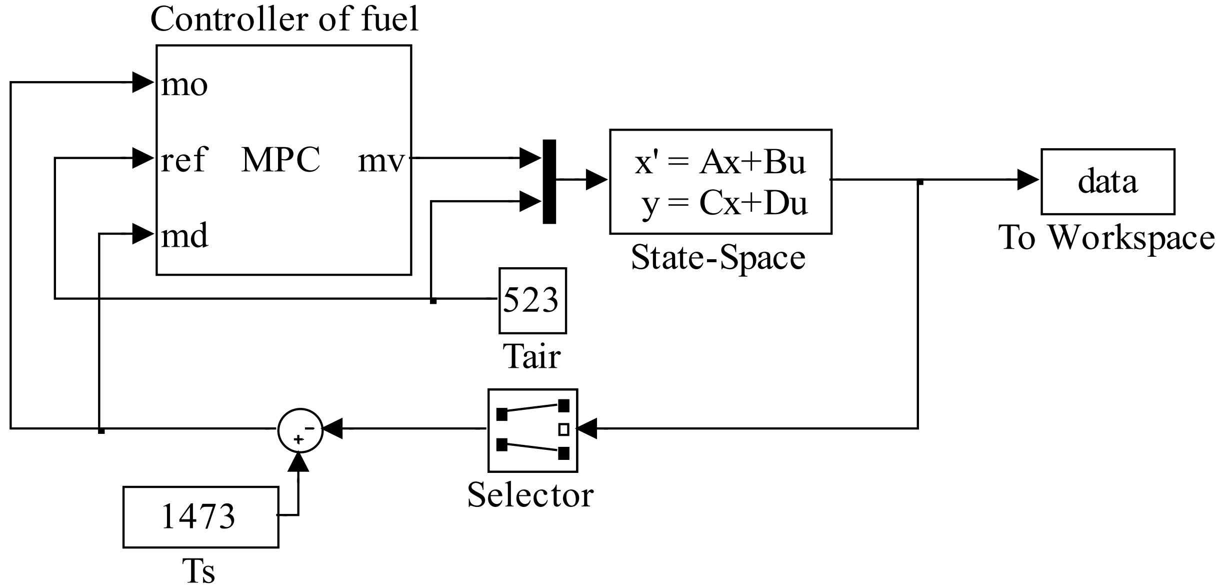

Fig. 2. - Simulink Model of system for reheat of slabs

The four state matrices are used in Simulink to construct a working model. In the figure below is the state space model representation within Simulink.

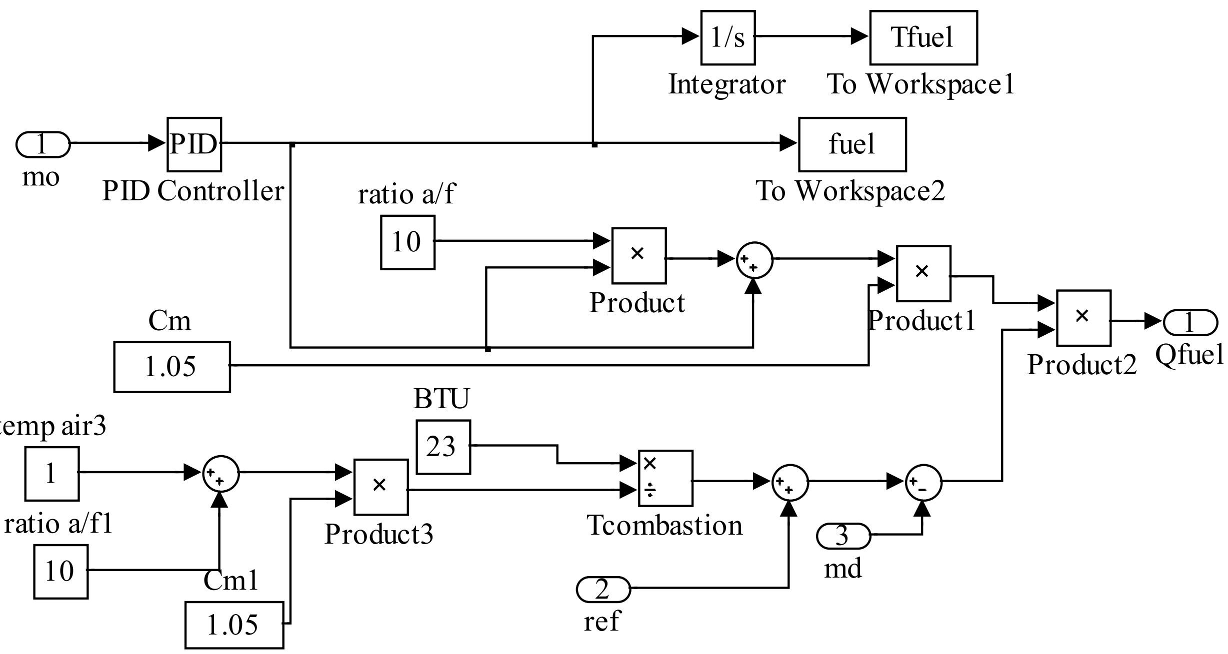

Fig. 3. - Net Heat Input Subsystem

Within the model there are two constants, the ambient air temperature and the slab set point temperature. The ambient air temperature is the air temperature outside of the furnace. The slab set point temperature is the desired steady state temperature of the slab; this temperature is approximately 1473 K.

The first large block is a fuel flow controller (fig. 2). The gains within the controller have been modified for optimal performance for my model. The second block is labeled the state space model block. Within this block Simulink accepts the model's inputs and then outputs the model's outputs. The output needed for furnace control is routed back to the fuel controller and the remaining outputs are collected in a data file for observation and plotting [6]. The output needed for furnace control is routed back to the fuel controller and the remaining outputs are collected in a data file for observation and plotting [7].

The rest of this routine calculates the net heat input using the fuel flow from the controller routine, the BTU of the fuel, and the ambient air temperature (fig. 3).

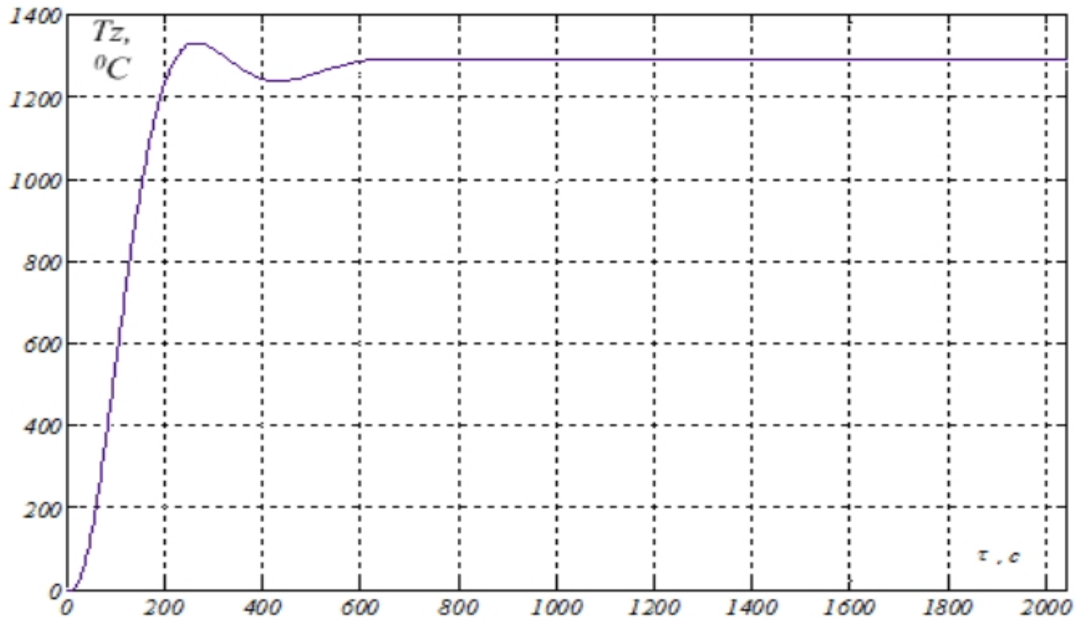

Fig. 4. - Transient of establishment of the temperature slab

The model could be simplified using a constant; however the model was left expanded so that the variables like BTU and A/F ratio could be easily changed.

Conclusions

The model controller is supervisory and can merely provide a set point and feedback signal to the gas valve controller. Different modes might be advantageous for different parts of the term cycle. Energy efficiency and slab quality will determine how the system is set up.

The mathematical model of the reheating furnace may be less accurate because the position of temperature measurement has less. The system identification method can be investigated the suitable mathematical model only system with explicit input and output [3].

The reheating furnace has many mode of input in heating curve up process. Therefore, it is necessary to approximately mathematical model.

Список литературы

1. Скоробогатова І.В. Питання стабілізації температурного режиму в томильній зоні методичної нагрівальної печі / І.В. Скоробогатова, Б.В. Гавриленко, С.В. Неежмаков // Наукові праці ДонНТУ. Серія «Обчислювальна техніка та автоматизація». – 2010. – Вип. 18(169).
2. Swarup Kumar Mahapatra. Simulation of heat transfer in furnace using fluent gambit / Swarup Kumar Mahapatra // Department of Mechanical Engineering National Institute of Technology Rourkela. – 2009.
3. . Estimation of the Mathematical Model of the Reheating Furnace Walking Hearth Type in Heating Curve Up Process / Jiraphon Srisertpol, Suradet Tantrairatn, Prarinya Tragrunwong and Vorapot Khomphis // International journal of mathematical models and methods in applied science. – 2011. – Is. 1. – Vol. 5.
4. Advanced steel reheat furnace. AFRC International symposium / D. Moyeda, M. Sheldon, R. Koppang, M. Lanyi, X.Li, B. Eleazer // 1997, DOE Grant No. DE-FG03-96ER 12200/A000
5. Biswabrata Pradhan. Controlling Energy Utilisation at Reheat Furnace Using Time Series Model / Biswabrata Pradhan, Ananya Mukhopadhyay, Bhagabat Maity // Heldermann Verlag, Economic Quality Control. – 2009. – Vol. 24. – No. 2. – P. 195-205.
6. Zenghuan Liu. An estimation temperature by analysis of and transient heating of a slab in reheating furnace / Zenghuan Liu and Likong Liin // Proc. 2 International Conference on ICICTA'09, Hunan, China. – 2009. – P. 532-535.
7. Lankarany M. Parameter estimation optimization based on genetic algorithm applied to DC motor / M. Lankarany and A. Rezazade // IEEE International Lahore, Pakistan. – April, 2007. – P.1-6.

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***Б.В. Гавриленко, І.В. Скоробогатова*. Розробка моделі адаптивної системи управління нагрівальної печі.** *Проаналізовано вплив основних чинників на встановлення заданого температурного режиму в методичній нагрівальній печі. Обґрунтовано необхідність реструктуризації діючої системи автоматичного керування температурним режимом в печі та підвищення якості нагріву металу за рахунок повного спалювання палива.*

Ключові слова: методична нагрівальна піч, параметри, управління, система, теплопередача, модель, якість.

***Б.В. Гавриленко, И.В. Скоробогатова*. Разработка модели адаптивной системы управления нагревательной печи.** *Проанализировано влияние факторов на установление заданного температурного режима в методической нагревательной печи. Обоснована необходимость реструктуризации действующей системы автоматического управления температурным режимом в печи и повышение качества нагрева металла за счет полного сгорания топлива*

Ключевые слова: методическая нагревательная печь, параметры, управление, система, теплопередача, модель, качество.