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DEVELOPMENT OF AUTOMATIC BOF STEELMAKING CONTROL SYSTEM BASED ON SUB-LANCE TECHNOLOGY[1]

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Abstract

Automatic control technology based on sub-lance detecting is an effective way to improve converter steelmaking process. Currently, the automatic BOF steelmaking control system based on the sub-lance technology has been developed by CISDI. This system is composed of basic automation system and process control system. The main feature of the system is using composite models, which integrate the knowledge of smelting mechanism, mathematical statistics, expert rules and adaptive learning. Besides, an operation interface has been introduced into the first-level control system, which makes the operation more flexible. The CISDI system has been applied in Shaosteel Plant. The results show that the re-blowing rate is about 30% less compared with the one of manual style. In addition, the melting time has been reduced by 3 minutes. The results indicate that the automatic control system of CISDI can not only meet the requirements of smelting process, but also improve production efficiency.

Key words: Converter; Automatic BOF steelmaking control; Control system; Sub-lance technology.

DESENVOLVIMENTO DE SISTEMA DE CONTROLE AUTOMÁTICO COM BASE EM TECNOLOGIA DE SUB-LANCE PARA FABRICAÇÃO DE AÇO EM BOF

Resumo

A tecnologia de controle automático com base na detecção por sub-lança é uma forma eficaz de melhorar o processo de fabricação de aço em conversor. Um sistema de controle automático para fabricação de aço em conversor LD com base na tecnologia de sub-lança foi atualmente desenvolvido pela CISDI. Este sistema é composto de um sistema de automação básica e outro sistema de controle de processo. A principal característica do sistema é utilizar modelos compostos, que incluem o conhecimento do mecanismo de fusão redutora, estatísticas matemáticas, regras especializadas e aprendizagem adaptativa. Além disso, uma interface de operação foi introduzida no sistema de controle de primeiro nível, o que torna a operação mais flexível. O sistema CISDI tem sido aplicado na Usina de Shaosteel na China. Os resultados mostram que a taxa de re-insuflação é cerca de 30% a menos comparado com o de estilo manual. Além disso, o tempo de fusão foi reduzido em 3 minutos. Os resultados indicam que o sistema de controle automático da CISDI pode não só satisfazer as exigências do processo de fusão redutora, mas também melhorar a eficiência da produção.

Palavras-chave: Conversor; Controle automático para fabricação de aço; Sistema de controle; Tecnologia de sub-lança.

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1 INTRODUCTION

Basic oxygen furnace (BOF) steelmaking is a complex physicochemical process. Since there are too many influencing factors existing, it is difficult to reach the endpoint of smelting process only by main-blowing. It is not good for productivity and cost effectiveness of steelmaking process. The automatic BOF steelmaking control technology based on sub-lance detecting is an effective way to improve the accuracy of endpoint control, shorten the smelting cycle, enhance the productivity and reduce the production costs.(1) Quite a few steel companies in China adopting this technology have obtained considerably good results, such as Baosteel, Shougang, Wuhan Iron and Steel, and so on.

Meeting the smelting requirements and achieving operational convenience play key roles in the successful application of an automatic control system. Currently, there are several control models, such as mechanism model, statistic model, incremental model, etc.(2-4) The mechanism model is based on the heat and mass conservation. It determines the relationship among variables by mathematical derivation. However, it is not suitable for application due to the complexity of the smelting process. The statistic model is based on the black-box theory.(3) The physicochemical process is ignored in this model. It only concerns on the statistical relationship between input and output parameters. The calculation accuracy of this model cannot be maintained as long as the smelting condition is changed. Using the incremental model, the operating parameters can be refined by comparing with the productivity data recorded. It can overcome the influence caused by the changes in the smelting conditions. However, the main shortcoming is low calculation accuracy. Generally, the automatic steelmaking control system consists of basic automatic control system (Level 1) and process control system (Level 2). The process control system governs the basic automatic control system. It judges the status of melting process by collecting the information from Level 1. Then it sends signals to Level 1 to control the adjusted parameters.(4) But in fact, there is no specific operation interfaces in Level 1. This means the users cannot modify the parameters in time when the smelting conditions change unexpectedly.

Above all, the automatic BOF steelmaking control system based on sub-lance technology developed by CISDI (CISDI system) has been described in this paper. A composite model has been used in the CISDI system. A special operation interface has been introduced into the first-level control system. And a typical industrial application of the CISDI system has been carried out in Shaosteel in China, and good results are obtained.

2 SYSTEM DEVELOPMENT

2.1 System Organization

The purpose of converter steelmaking process is to adjust the composition and temperature of molten steel. According to the process requirements, the CISDI system is composed of basic automation system and process control system. The system organization is shown in Figure 1.

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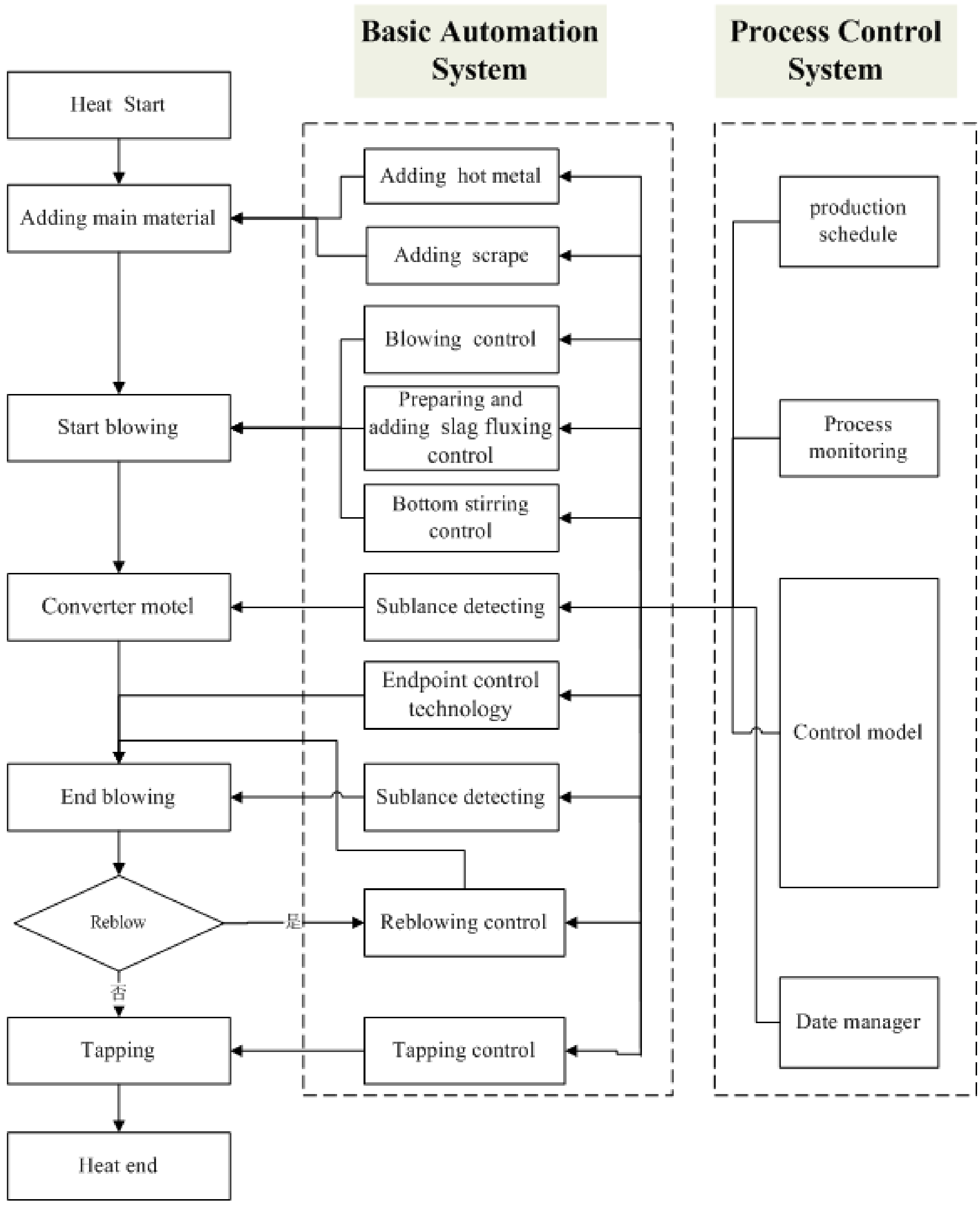

Figure 1. System organization.

The main functions of the basic automation system include oxygen lance control, auxiliary material control, bottom stirring control, sub-lance detecting control and endpoint control. The process control system performs production management, control model, process control and data management. The process control system is used to dominate the basic automation system. Firstly, it collects information about melting process and sub-lance detection. Then it judges the status of melting process according to the results of model calculations. Finally, it sends signals to the basic automation system to control the adjusted parameters.

2.2 Sub-Lance Detecting Technology

Using sub-lance detection technology, a lot of important information, such as temperature, carbon content and oxygen content, can be obtained. Then, the information of carbon content and temperature can be used to improve the accuracy of melting endpoint control by adjusting the consumptions of coolant and oxygen.

The sub-lance functions as a sampling device, which can be applied to optimize the blowing and slag-forming rules. Compared with the existing technology, the sub-lance system developed by CISDI has the following characteristics:

- Double power sources design is performed for lifting of the converter sub-lance. When working correctly, the main transmission will be disconnected from the emergency transmission system and it can keep the emergency transmission static and avoid abrasive wear. The electro-hydraulic thruster brake with an actuating cylinder is provided here. The emergency electric motor can lift the sub-lance system smoothly when the main motor and the electro-hydraulic thruster brake break down, also in case of power-off accident. Spur gears are used in the lifting gearbox, which provide the equipments with more reliable working conditions and convenient maintenance;
- a ratchet drop-preventing device and a steel rope balancer are included in the sub-lance carrier. The two steel ropes will work in a balanced operating condition all the time, allowing the sub-lance to work in a more reliable and safe manner;
- a sloping conveying structure with large angle is used in the conveying probe device, which is simple and easy to fabricate;
- a nesting structure is designed in the probe tilting mechanism, which can be assembled and disassembled easily. An articulated mechanism is provided to guide and clamp the probe. The design can be adapted to three-dimensional plug and improve the smoothness of the operation. Also, the use of the standard and common parts for the core component can simplify the mechanical system;
- the nitrogen seal valve consists of two dimidiate plates, allowing for more efficacious slag removal.

2.3 Control Models

The control models are the core part of the automatic steelmaking control system, which integrates the knowledge of smelting mechanism, mathematical statistics, expert rules and adaptive learning. The control equations are derived using the knowledge of smelting mechanism. And the key control parameters are defined by mathematical statistics and expert rules. Moreover, these control parameters can be regularly modified through adaptive learning. The control models refer to the main materials model, slag-forming model, temperature model, oxygen consumption model, alloy model, dynamic control model and adaptive learning model. The functions of the models are shown in Figure 2.

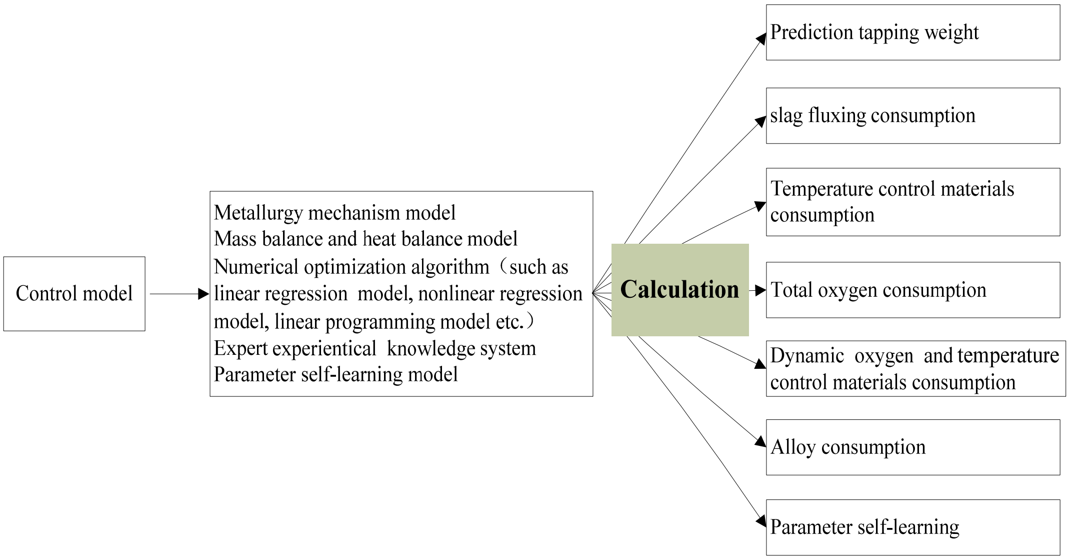

Figure 2. The model function structure.

2.4 Operation Interface

To provide the system with a good flexibility, an operation interface specific for steelmaking has been incorporated in the basic automation system. The user can easily control the converter smelting process by using this interface. And the important information of steelmaking process can be modified and fed back to the process control system, thus achieving the desired accuracy of the control models. Besides, users can adjust the control parameters in time during the blowing process according to the smelting performance.

3 INDUSTRIAL APPLICATIONS

The CISDI system has seen successful application in Shaosteel. Prior to the start of the smelting process, a series of control parameters have been set through the operation interface, such as lime consumption, oxygen consumption and sub-lance detecting time, etc. Then auxiliary material preparation and charging control have been executed by basic automation system. When the smelting process started, the basic automation system began to carry out instructions from the process control system, such as oxygen lance control, auxiliary material control, bottom stirring control, sub-lance detection control and endpoint control. The tested results of the automatic steelmaking control system are shown in Table 1.

Table 1. Tested results of the automatic steelmaking control system

	Melting Time (in min)	Re-blowing Rate (in %)
Manual steelmaking	~33	~50
Automatic steelmaking	~30	~20

It can be seen in Table 1 that the re-blowing rate of steelmaking process is 20%, which is 30% lower than that of the manual steelmaking process. In addition, the melting time has been reduced by 3 minutes if compared with that of the manual steelmaking process.

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4 CONCLUSIONS

The automatic BOF steelmaking control system based on sub-lance technology has been developed by CISDI. This system is composed of basic automation system and process control system. The system features composite models which integrate the knowledge of smelting mechanism, mathematical statistics, expert rules and adaptive learning.

The CISDI system has been applied in Shaosteel. The results indicate that the CISDI system can not only meet the requirements of smelting process, but also improve production efficiency.

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