Vol. 6 №. 1 TRANSACTIONS OF NFsoc Mar. 1996

EXPERT SYSTEM FOR SINTER CHEMICAL COMPOSITION CONTROL BASED ON ADAPTIVE PREDICTION[①]

Fan Xiaohui, Wang Haidong, Chen Jin, Huang Tianzheng
Department of Mineral Engineering,
Central South University of Technology, Changsha 410083
Yang Shinong, Wang Yueli, Zheng Tianzhong
Anshan Iron & Steel Co., Anshan 114021

ABSTRACT In order to stabilize the sinter chemical composition, the expert system for composition control based on adaptive prediction has been developed on the basis of modern control theory and artificial intelligence. It has been verified by using real data at No. 3 Sintering Plant of Anshan Iron and Steel Co., and satisfactory results have been obtained.

Key words sinter chemical composition adaptive prediction expert system for control

1 INTRODUCTION

The stability of sinter chemical composition is the key of keeping stable operation of the blast furnace. At present, sintering plant has been mostly confined to controlling the blending bed and keeping constant feed rate.

However, due to raw materials' slow changing (such as composition and grain size) and quick changing (such as moisture), long time delays and dynamic complexity of the process, the efficiency of conventional composition control is relatively limited. The adaptive prediction method can recognize any change in the process dynamic and can automatically adapt itself by adjusting the process model parameters accordingly, which compensates time delays.

At the same time, the variance of one composition may result in all others. Various compositions are so closely interrelated that the operation relies heavily on the experience of operators. Therefore, the expert system for composition control based on the skilled operators' experience and knowledge was developed at Anshan Iron and Steel Co.

This paper describes the content of the expert system for composition control based on adaptive prediction (PCES) and the testing result.

2 CONTENTS OF PCES

The objective of PCES is to maintain stable sinter composition at the setpoints. Its schematic diagram is shown in Fig. 1.

At 2 h intervals, real-time plant data were taken into the system. First data-processor filtered and processed data; Second the estimator updated parameters of models based on the processed data (u' and y') at current time and past time; Next the predictor predicted the future chemical composition in 2 h ahead; Then depending on current data and predicted values, expert system judged the states of chemical compositions by comparing

① Supported by the National Natural Science Foundation of China and Key Program of the 8th Five-Year Plan of China;
Received Oct. 13, 1995, accepted Nov. 16, 1995

with the present boundary values; Whenever one of the states did not meet the standards, expert system analysed the causes of problems and instructed how to make adjustment percentage proportion.

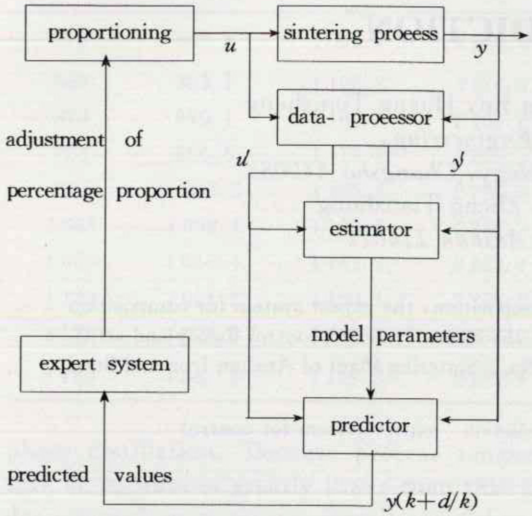

Fig. 1 Schematie diagram of PCES

3 ADAPTIVE PREDICTOR

The objective of the predictor was to predict the chemical composition of sinter, so the output variables were TFe, FeO, SiO_2, CaO, MgO content of sinter; There were many variables influencing the composition of sinter, such as raw materials, operating variables and sintering process itself. Here the main influencing factor was raw materials (including return fines) to be considered as input information.

3.1 *Predictive Model*

The process was considered as a "grey box" system, and its dynamics were described via input-output model (SISO model as example):

$$A(z^{-1})y(k) = B(z^{-1})u(k)z^{-d} + e(k) \qquad (1)$$

where $A(z^{-1}) = 1 + a_1 z^{-1} + \cdots + a_n z^{-n}$, $B(z^{-1}) = b_0 + b_1 z^{-1} + \cdots + b_n z^{-n}$, $y(k)$ output variable, $u(k)$ input variable, d time delay, z^{-1} backward shift operator and $z^{-1}y(k) = y(k-1)$, n model's orders, $e(k)$ white noise with zero mean value.

The optimal predictor is deduced as follows:

$$\hat{y}(k+d/k) = \hat{\alpha}(z^{-1})y(k) + \hat{\beta}(z^{-1})u(k) \qquad (2)$$

where $\alpha(z^{-1}) = \alpha_1 + \cdots \alpha_n z^{-(n-1)}$,

$\beta(z^{-1}) = \beta_0 + \beta_1 z^{-1} + \cdots + \beta_{n+d-1} z^{-(n+d-1)}$

Prediction of each output involves the following stages:

(1) parameter estimation: $y(k) = \varphi^T(k-d)\theta + \varepsilon(k)$

(2) d step ahead prediction:

$$\hat{y}(k+d/k) = \varphi^T(k)\hat{\theta}(k) = \hat{\alpha}(z^{-1})y(k) + \hat{\beta}(z^{-1})u(k)$$

where $\theta = [\alpha_1, \cdots, \alpha_n, \beta_0, \cdots, \beta_{n+d-1}]$,

$\varphi^T(k) = [y(k), \cdots, y(k-n+1), u(k), \cdots, u(k-n-d+1)]$

3.2 *Structure of System*

The adaptive prediction was made up of data-processor, estimator and predictor.

Data-processor: Due to the chance stop-start of sintering strand and occasional failure of various sensors, the data obtained from N-90 are liable to be inaccurate. The contents of sinter composition may be not precise because of the error of chemical analysis. The inaccurate information must result in inaccurate model. Therefore, it is necessary to judge and filter the abnormal sampling data.

Estimator: Time delays and order were determined by off-line structure identification and process knowledge. The recursive least squares (RLS) method was used to estimate the parameter of model, and exponential forgetting algorithm was presented to solve the problem of real-time estimation.

Predictor: On the basis of models updated by estimator, predictor predicted output values 2 h ahead.

4 EXPERT SYSTEM FOR CONTROL

The variance of TFe content may be caused by the following cases: (1) varying of the flowrate of iron-bearing materials; (2) varying of the kinds of iron-bearing materials;

(3) varying of sinter basicity. The variance of TFe content certainly gives rise to the change of SiO_2 content.

The change of basicity (R (CaO/SiO_2)) may result from the following two causes: (1) the variance of CaO; (2) the variance of SiO_2 content.

FeO content may vary due to the variance of raw materials and operation conditions.

The objective of this subsystem is to determine the real causes and instruct efficient action on the basis of domains expert and skilled operator's experience and heuristic knowledge.

Fig. 2 shows architecture of the expert system for control (CES).

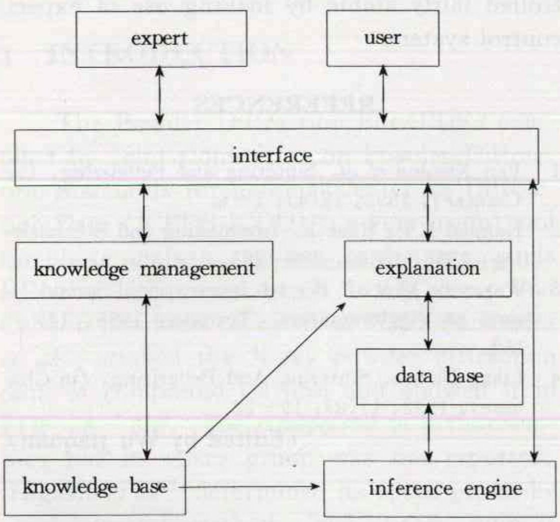

Fig. 2 Architecture of expert system for control

Knowledge Base: The quality of knowledge representation has important influence on the knowledge management, knowledge explanation, problem-solving and so on. Knowledge used in CES includes certain and incertain knowledge, heuristic and factual knowledge, quantitative and qualitative knowledge. In order to represent the different knowledge, many kinds of knowledge representation technique (such as production rule, predicate logic, frame and procedure representation method) are used.

Inference Engine: Inference engine supervises a series of hypotheses and deductions for arriving at conclusions. It has closely relation with knowledge representation and the knowledge base architecture. In order to implement judgement and instruction, the control strategies of forward reasoning, approximate reasoning and procedural reasoning were adopted; The depth-first search strategy was used.

Data Base: Data base was prepared for the system to save data which was produced or used.

Explanation System: For the purpose of transparency of system, explanation system was developed to explain how to deduce the conclusion.

Knowledge Mangement: Knowledge management was developed in order to be used for modifying the knowledge base conveniently.

CES is such a process: judging the states of compositions based on the prediction information; determining the causes of problems if the states are outside standards; on the basis of states and causes, instructing quantitative or qualitative action to be taken.

5 RESULTS

Fig. 3 demonstrates that the adaptive predictor shows adaptability and accuracy good enough to meet the variance of the input variables and the imposed perturbations. Table 1

Table 1 Result of prediction and operation guide

Aug. 10 1995
3:00

SINTER CHEMICAL COMPOSITION CONTROL

COMPOSITION	TFe	SiO_2	CaO	R	FeO
PREDICTION	53.7	7.21	13.91	1.96	7.3
STATE	HH	L	H	HH	L
CAUSE	percentage of limestone is high; component of blending iron-bearing materials is mistaken				
MEASURE	decrease percentage of limestone by 1.0%				

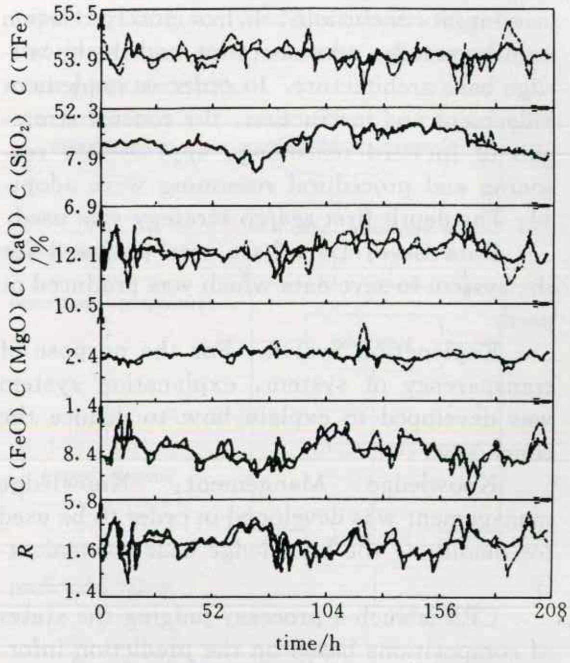

Fig. 3 Prediction of sinter chemical compositon
——measurement; ······prediction

shows the results of prediction and operation guide.

6 CONCLUSION

Expert system for control based on prediction (PCES) has been developed and applied to stablize the sinter composition at No. 3 Sintering Plant of Anshan Iron and Steel Co.. It has been demonstrated through simulation studies and plant implementation trials that as follows:

(1) The adaptive prediction can be very useful and sensible in foreseeing the sinter composition several hours in advance.

(2) The sinter composition can be controlled fairly stable by making use of expert control system.

REFERENCES

1 Fan Xiaohui *et al*. Sintering and Pelletizing, (in Chinese), 1993, 18(4): 1−6.

2 Kanjilal P P, Rose E. Ironmaking and Steelmaking, 1986, 13(6): 289−293.

3 Watanabe M *et al*. In: 4th International Symposium on Agglomeration. Toronto: 1985: 147−152.

4 Liang Dichao. Sintering And Pelletizing, (in Chinese), 1992, 17(2): 19−22.

(Edited by Wu jiaquan)