Research on Typical Working Conditions of Calcining Zone Temperature

Fen Wang[1, a*], Xiaohong Wang [1, b] ,Hongliang Yu[1,c]

[1]School of Electrical Engineering University of Jinan, Jinan 250022, China

[A]1824783382@qq.com, [b] cse_WXH@ujn.edu.cn,[c]ziliao_yhl@163.com

Keywords: Calcining Zone Temperature;LS_SVM;Typical Working Conditions

Abstract. Cement rotary kiln calcining process is a complex nonlinear dynamic systems, but most of the time appears in the system of continuous dynamic characteristics and fluctuates around working conditions. So in this article, we established the recognizer of working conditions that fits the cement calcining process, and established soft measurement models for each of the identified typical working conditions with corresponding Calcining Zone temperature. Using LS_SVM to establish the soft measurement model and by selecting appropriate dominant variable number of soft measure f_CaO indirectly get the calcining zone temperature.

Introduction

In the process of cement production, cement calcining process is a complex nonlinear dynamic system, which link is the calcining of rotary kiln monitoring devices in the system. At the same time in determining the quality of clinker in the cement rotary kiln is calcining zone temperature, but the temperature of calcining zone can't accurate detection, at present mainly through high temperature color machine or cylinder scanner to get roughly calcining zone temperature[1], so the real-time control of rotary kiln has certain constraints. Considering under certain conditions for the linear relationship between f_CaO and temperature of calcining zone, when calcining temperature is 1300˚C, f_CaO content is 6.4%, when the temperature up to 1400 ˚C, the f_CaO content reduced to 1.3%[2,3], So we can through the soft measurement real-time f_CaO indirectly get real-time calcining zone temperature.

In this article, through the different related variables to establish the recognizer of working conditions. Identified the typical working conditions to establish the corresponding soft measurement models of calcining zone temperature. In References [4,5] to select the three main variables related to the calcining zone temperature, smoke chamber temperature, the main motor current of rotary kiln, the kiln hood temperature as the model input; But through the empirical analysis, relevant variables and factors influencing the temperature of calcining zone-precalciner outlet temperature and cooler speed. In this paper, by selecting the five main variables as input, the soft measurement model experimental trial and error method is used to select LS_SVM related parameters calcining zone temperature soft measurement model is established.

Establish Working Condition of Recognizer

Design recognizer mainly by looking for the variables that can monitor in the calcining system. Under the different typical operating conditions, we can through the monitoring parameters of baseline values for condition classification. Combined with actual operation experience, a cement company is closely related to the rotary kiln process parameters, and the stability degree of these parameters, eventually determine the working condition of raw feed rate (X_1) , elevator current (X_2), precalciner outlet temperature(X_3), kiln speed(X_4), smoke chamber temperature(X_5), the main motor current of rotary kiln (X_6) , the kiln hood temperature (X_7) , kiln hood coal injection (X_8) , cooler speed (X_9) as input of recognizer.

Typical working condition 1:

$$
\begin{aligned}
&(X_1 \to 243.9 \pm 11.1) \wedge (X_2 \to 135.81 \pm 2.32) \wedge (X_3 \to 938.225 \pm 32.375) \\
&\wedge (X_4 \to 3.7 \pm 0.07) \wedge (X_5 \to 1218 \pm 40) \wedge (X_6 \to 500 \pm 60) \wedge \\
&((X_7 \to 1125.69 \pm 80)) \wedge ((X_8 \to 11.3 \pm 0.1)) \wedge ((X_9 \to 9.87 \pm 1.18))
\end{aligned} \quad (1)
$$

Typical working condition 2:

$$
\begin{aligned}
&(X_1 \to 246 \pm 8) \wedge (X_2 \to 135 \pm 5) \wedge (X_3 \to 935.8 \pm 30) \\
&\wedge (X_4 \to 3.725 \pm 0.095) \wedge (X_5 \to 1173 \pm 233) \wedge (X_6 \to 454 \pm 58) \wedge \\
&((X_7 \to 1050.65 \pm 80)) \wedge ((X_8 \to 11.1 \pm 0.1)) \wedge ((X_9 \to 9.52 \pm 1.32))
\end{aligned} \quad (2)
$$

Typical working condition 3:

$$
\begin{aligned}
&(X_1 \to 229.86 \pm 13.135) \wedge (X_2 \to 135.06 \pm 4) \wedge (X_3 \to 911.62 \pm 27.65) \\
&\wedge (X_4 \to 3.8145 \pm 0.095) \wedge (X_5 \to 1114.5 \pm 117.315) \wedge (X_6 \to 472.3 \pm 70) \wedge \\
&((X_7 \to 1097.2 \pm 100)) \wedge ((X_8 \to 10.9 \pm 0.1)) \wedge ((X_9 \to 11.27 \pm 2.36))
\end{aligned} \quad (3)
$$

The Method of Soft Measure Calcining Zone Temperature

By analyzing the mechanism of rotary kiln calcining system and personnel's experience shows: related parameters affect the calcining temperature is under the outlet temperature of precalciner, smoke chamber temperature, the main motor current of rotary kiln, the kiln hood temperature and the cooler speed, etc. Based on the above five parameters as the dominant variable, compared with the reference [5] in terms of increased the number of dominant variable, and found in the following model to realize f_CaO soft measurement error is smaller.

Data Processing Method.

Due to the dominant variable for the real-time data from the field need for data preprocessing, remove outliers and average processing, outliers eliminating adopts Rule of pauTa method, reduce the data range using average data method, pretreatment effect is shown in figure 1.

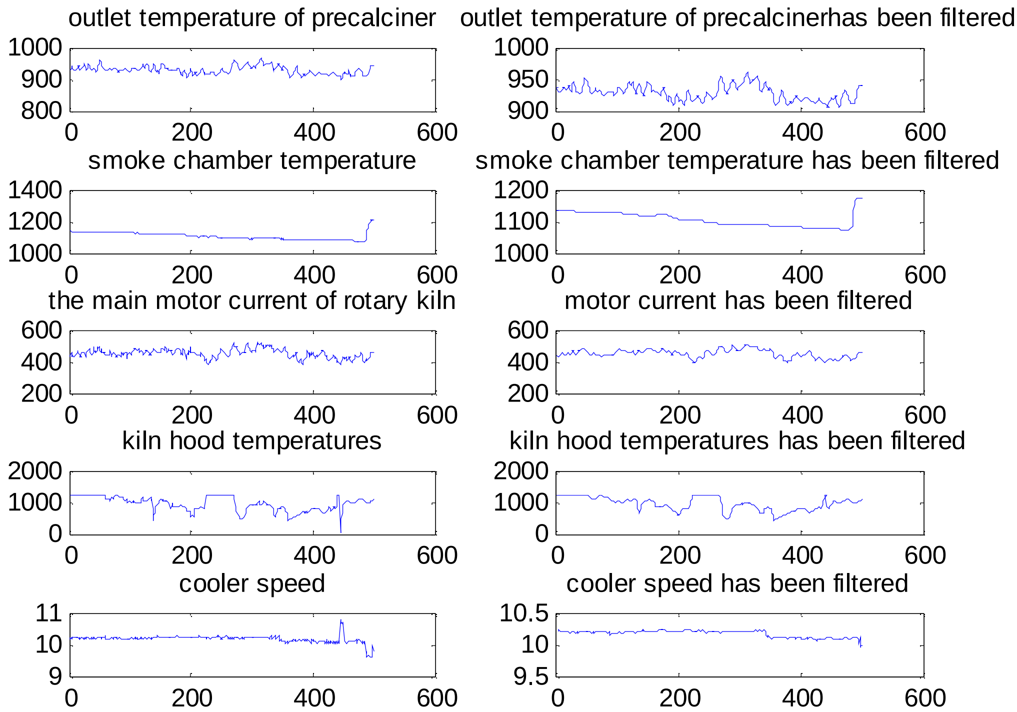

Fig. 1. data processing

Briefly Introduce the Soft Measurement Algorithm.

The data sample of $\{x_i, y_i\}$, $i = 1,2,\ldots,N$,input data $x_i \in R$,output data $y_i \in R$ .Least squares support vector machine algorithm formula as shown below[6,7].

$$y(x) = \sum_{i=1}^{N} l_i \bullet k(x_i, x) + b \tag{5}$$

In the formula expression, $l_i = C \cdot e$, the RBF kernel function is defined as:

$$k(x_i, x) = \exp(\frac{(x - x_i)^2}{2s^2}) \tag{6}$$

The regression model is defined as:

$$y(x) = \sum_{i=1}^{N} l_i \cdot \exp(-\frac{(x - x_i)^2}{2s^2}) + b \tag{7}$$

As can be seen by a formula, C, s selection based on least squares support vector machine model for sure play a key role.

Established the Calcining Zone Temperature Model Based on LS_SVM

Soft Measurement Model of the Nonlinear Part.

When determining C, s , test results are shown in table 1. Error calculation method for $\left[\sum_{i=1}^{N}\frac{(y_i - y_{i'})^2}{n}\right]^{\frac{1}{2}}$: among them, mse_xl as f_Cao model training error, mse_cs as f_Cao model test error; mse_xll as calcining zone temperature model training error, mse_css as calcining zone temperature model test error. By comparison with table 1, choosed the optimal C = 50; s = 0.6; mse_xl = 0.0168; mse_cs = 0.2266;mse_xll = 0.3352 ; mse_css = 4.5328.

Table.1 parameter selection and error values 1

C	s	mse_xl	mse_cs	mse_xll	mse_css
150	1	0.0156	0.2461	0.3117	4.9221
150	1.5	0.0361	0.3004	0.7222	6.0078
150	0.9	0.0125	0.2368	0.2507	4.7368
150	0.6	0.0060	0.2270	0.1207	4.5397
150	0.4	0.0037	0.2432	0.0750	4.8644
100	0.6	0.0089	0.2268	0.1207	4.5397
80	0.6	0.0109	0.2267	0.2185	4.5346
50	0.6	0.0168	0.2266	0.3352	4.5328
30	0.6	0.0261	0.2270	0.5226	4.5393
20	0.6	0.0365	0.2279	0.7293	4.5587

Based on the above model, we can see that established the calcining zone temperature model of nonlinear link has a larger error.

Conditions of Calcining Zone Temperature Soft Measurement Model.

Cement rotary kiln systems of the entire production process is non-linear, but at specific points within the model of linear relationship. Through the analysis of field data, established different soft measurement model that fits different working conditions.

Under the Frist Condition of Soft Measurement Model.

Condition recognition based on historical data, when under the frist condition of soft measurement model, By comparison with table 2, choosed the optimal C = 200; s = 1; mse_xl = 0.0017; mse_cs = 0.1671; mse_xll = 0.0339 ; mse_css = 3.3420.

Table.2 parameter selection and error values 2

C	s	mse_xl	mse_xl	mse_xll	mse_css
200	1.5	0.0022	0.1693	0.0449	3.3865
200	1	0.0017	0.1671	0.0339	3.3420
100	1.5	0.0044	0.1698	0.0882	3.3962
100	1	0.0034	0.1676	0.0673	3.3521
100	0.5	0.0030	0.1846	0.0590	3.6924
90	0.5	0.0033	0.1847	0.0655	3.6945
90	0.3	0.0033	0.2091	0.0650	4.1818
85	0.3	0.0034	0.2091	0.0688	4.1827
80	0.6	0.0037	0.1779	0.0744	3.5583
80	0.4	0.0037	0.1948	0.0732	3.8961

Under the Second Condition of Soft Measurement Model.

By comparison with table 3, choosed the optimal C = 300; s = 0.6; mse_xl = 0.0017; mse_cs = 0.1980; mse_xll = 0.0341 ; mse_css = 3.9603.

Table.3 parameter selection and error values 3

C	s	mse_xl	mse_cs	mse_xll	mse_css
300	1	0.0032	0.2206	0.0635	4.4116
300	0.5	0.0015	0.1997	0.0294	3.9947
300	0.6	0.0017	0.1980	0.0341	3.9603
200	0.5	0.0022	0.1999	0.0439	3.9974
200	1	0.0047	0.2198	0.0940	4.3951
100	1.5	0.0171	0.2448	0.3413	4.8957
100	1	0.0090	0.2175	0.1809	4.3501
100	0.5	0.0043	0.2003	0.0869	4.0053
90	0.5	0.0048	0.2004	0.0963	4.0071
90	0.3	0.0038	0.2215	0.0757	4.4303
85	0.3	0.0040	0.2216	0.0801	4.4311

Under the Thrid Condition of Soft Measurement Model.

By comparison with table 4, choosed the optimal C = 200; s = 2.0; mse_xl = 0.0068; mse_cs = 0.1663; mse_xl = 0.1357 ; mse_cs = 3.3257.

Table.4 parameter selection and error values 4

C	s	mse_xl	mse_cs	mse_xl	mse_cs
100	0.8	0.0038	0.1792	0.0752	3.5837
150	0.8	0.0025	0.1791	0.0505	3.5825
200	0.8	0.0019	0.1791	0.0380	3.5820
200	1	0.0023	0.1727	0.0465	3.4544
200	1.5	0.0040	0.1674	0.0809	3.3470
200	2.0	0.0068	0.1663	0.1357	3.3257
200	2.5	0.0106	0.1655	0.2114	3.3096
200	3.0	0.0153	0.1645	0.3062	3.2906
200	3.5	0.0208	0.1635	0.4157	3.2699
300	2.5	0.0074	0.1677	0.1474	3.3543

Based on the nonlinear link f_CaO and calcining zone temperature soft measurement modeling and typical working conditions of each model of the soft measurement modeling, we can know that by dividing condition of soft measurement model is more accurate. Table 5 shows the error between the entire link soft measurement model and the soft measurement model under the condition. Table 6 for corresponding with the calcining zone temperature soft measurement error. By error value is obvious in the points under the condition of soft measurement model precision is higher.

Table.5 f_CaO soft measurement comparison

Soft measurement method	C	s	mse_xl	mse_cs
The nonlinear link	50	0.6	0.0168	0.2266
condition 1	200	1	0.0017	0.1671
condition 2	300	0.6	0.0017	0.1980
condition 3	200	2.0	0.0068	0.1663

Table.6 Calcining zone temperature soft measurement comparison

Soft measurement method	C	s	mse_xl	mse_cs
The nonlinear link	50	0.6	0.3352	4.5328
condition 1	200	1	0.0339	3.3420
condition 2	300	0.6	0.0341	3.9603
condition 3	200	2.0	0.1357	3.3257

Summary

This paper was done three works: soft-sensing model of the dominant variables used in this article are different in the past references.In this article, increased the number of dominant variable are the five main variables, through the comparison and reference used in the past three dominant variable error value is smaller, the established model precision is higher;through an analysis of field data, condition recognition is established, divided into three of typical operating conditions;The cement rotary kiln firing process is a complex nonlinear dynamic model, first of all, setting up a suitable for the soft measurement model of nonlinear condition, at the same time, considering that although the whole burnt link is nonlinear, but at a particular point within the model is a linear relationship, so based on the typical working conditions of the corresponding soft sensor model, and by comparing the precision of soft sensor model based on typical working condition is superior to the nonlinear model of the part.

Acknowledgements

This work is supported by Shandong Province Department of Education Fund Project under J12LN17.

References

[1]Lei Ting,The measuring and controlling system of cement kiln [D].Inner Mongolia University,2006.

[2]Lei Ting,The measuring and controlling system of cement kiln [D].Inner Mongolia University,2006.

[3]Wang Guangdong.New dry-process cement production line optimization system of process indicators[J].China Cement,2010,12:57-60.

[4]Wang Zuo,Yuan Mingzhe,Wang Hong,Wang Tianran.Cement clinker quality of soft measurement modeling research [J].Control and Instruments in Chemical Industry,2006,06:53-54+58.

[5]Liu Wenguang,Wang Xiaohong,Yu Hongliang,Wu Jingjian,et al.Soft-sensor for f-CaO in cement clinker calcination process based on LS-SVM. Control Engineering of China ,2008,S2:85-88.

[6]Li C H,Zhu X J, Cao G Y, Sui S, Hu M R.Identification of the hammerstein model of a PEMFC stack based on least squares support vector machines[J].Journal of Power Sources, 2008,175:303–316.

[7]Ekici B B.A least squares support vector machine model for prediction of the next day solar insolation for effective use of PV systems[J].Measurement,2014,50:255-262