Study on Optimal Setting of Decomposing Furnace Temperature Based on Soft Measurement

Hong Liang Yu, Guo Dong Lian and Xiao Hong Wang

1 Preface

In the production process, when the cement raw meal (the main ingredient is limestone) through the kiln hoist into the preheater, it would exchange heat with high temperature flue gas, and the pre decomposition process occurs, then the mixture was sent into the claimer. At the same time, the coal was sprayed into the decomposition furnace, with the assist of tertiary air, the mixture combustion violent; when majority of limestone was decomposed, raw meal was dropped from the decomposing furnace and getting into rotary kiln been calcined and decomposition rate of kiln was one of the important control targets, which refers to the percentage of carbonate decomposed during the raw meal throughing decomposing furnace and lower preheater, before entering the kiln. Generally the range of decomposition rate is 90–95%. If the decomposition rate is too low, it will increase the final energy consumption of cement clinker and if the decomposition rate is too high, it is very prone to bring sintering blockage disastrous. In cement production process, the decomposition rate is determined by the temperature of decomposition furnace.

But at this stage, the temperature's control of decomposition furnace finished by artificial, few cement production lines were achieved automatic control, seen the literature [1–5]. However the temperature's setting of decomposing furnace is still completed by operator, which refers to the interval value of decomposition rate about raw meal given by laboratory, this can't ensure the science and real time of setting value, There is a certain gap between the level of automation and the international advanced cement production line, and this situation cannot meet the increasing quality and energy consumption control requirements of cement enter-

H.L. Yu (✉) · G.D. Lian · X.H. Wang
School of Electrical Engineering, University of Jinan, Jinan, China
e-mail: ziliao_yhl@163.com

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prises. for this reason, this paper has been carried on the related research, and proposed the corresponding solution.

2 Study on the Soft Measurement of the Decomposition Rate of the Kiln

In present period the decomposition rate of raw meal; cannot be detected online sampling and testing at intervals in most companies (once a day or eight hours a day) and The detection value of this kind of method is obviously not conducive to the automatic temperature optimization of the decomposition furnace. And the literature [6] has made a preliminary study on the online soft measurement of the decomposition rate of raw meal (The same research group), To this end, this paper carried out some reference. But this thesis is based on the production process of Shandong cement plant, cement production line process and document the differences, and in order to further improve the versatility of raw meal decomposition rate of soft measuring method, we improved the selection of dominant parameters and specific algorithm.

2.1 Selection of Dominant Parameters

(1) Enhance mechanical and electrical flow into the kiln: The enhance mechanical and electrical flow into the kiln can not only reflect the number of raw material into the kiln in real-time Through the current fluctuations, and the distance of preheater closer, better real-time, therefore, this paper selects one of the variables as auxiliary variables.
(2) Decomposition furnace temperature and pressure: decomposition furnace should provide enough heat to support the decomposition of raw materials, ensure the kiln before raw meal decomposition rate in more than 90%, so the decomposition furnace temperature and pressure is the main parameters of soft measurement.
(3) Three wind temperature: the three wind is a part of the decomposition furnace combustion with wind, and the temperature is higher, so the stability of the furnace temperature and the temperature of the tertiary air has a great relationship.
(4) Five stage preheated cone inlet temperature and pressure: according to field technology, from the decomposition of the furnace to the smoke room still need three minutes, the three minutes is through the time of the 5 stage preheated, in addition, through the off-line laboratory data, the 5 stage preheated sometimes B and A decomposition rate of the sample gap is larger, so it can be determined that the 5 stage preheated has a greater impact on the decomposition rate.

2.2 Data Preprocessing

(1) Abnormal data elimination

AS the decomposition rate based on cement plant was sampled and tested at 6 PM, therefore, the first three minutes of 6 PM per day the data was selected and Pull the Rule was used to eliminate.

(2) Mean filter

After eliminating the abnormal data, through the mean filter to further improve the smoothness of the data, Average three minutes before six pm every night to remove outliers.

(3) Data standardization

And then through the data standardization, all of the parameters to select the appropriate range of transformation, data processing for the [−1,1] range of the data.

The above three types of methods are more common, so the specific algorithm is no longer described.

2.3 The Soft Measurement Model of the Decomposition Rate of the Kiln

Least squares support vector machine (LS_SVM) has many advantages, for example, it does not have the local minimum, which causes the phenomenon of excessive learning, and the convergence rate is faster than that of the neural network. So the LS_SVM method is used to build the model of the soft sensor of the kiln decomposition rate. The main need to determine the two parameters, one for the penalty factor, and the other for the parameter of the kernel function.

After repeated trials and selection, the final punishment factor $C = 50$, Kernel function using radial basis function, the Kernel width is $\sigma = 3.0$. Based on these two variables, the estimated function is $\alpha = \begin{bmatrix} 26.9273 \\ -32.8816 \\ \vdots \\ -4.5123 \end{bmatrix}_{45\times 1}$, $b = -0.1487$, modeling the data to get the modeling results and test results as shown in Fig. 1.

As can be seen from the figure, even in the case of substandard data, it can be very good to follow, and the forecast is more accurate.

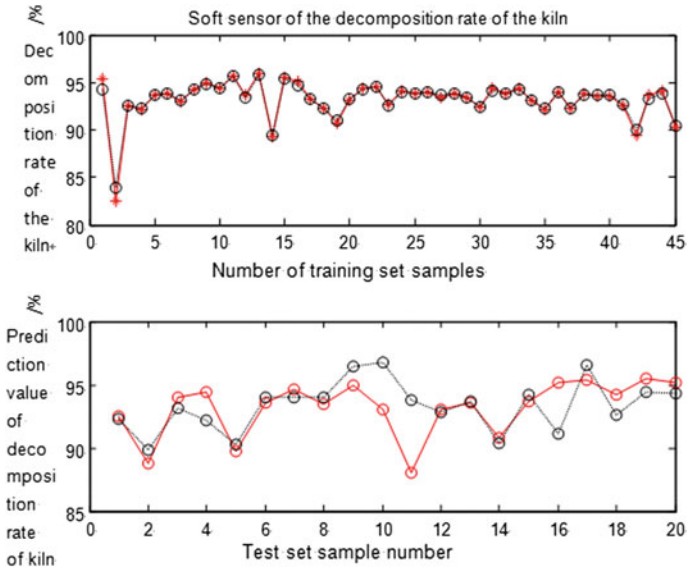

Fig. 1 Least squares support vector machine learning and test results

3 Control System of Kiln Decomposition Rate Based on Fuzzy Control

After realizing of the online soft measurement of the decomposition rate of the kiln, we give the automatic control system of the decomposition rate of raw meal. The plan is shown in Fig. 2.

Decomposition rate optimal control system is divided into two parts, the first part is through the OPC to exchange data between database and the DCS of cement site, the data in the database will be flitted and estimated model by the algorithm system, then evaluating the raw material pre decomposition rate of raw material related to this time, The other part is to calculate the burn index of the raw material through the three rate values from laboratory.

3.1 Burn Ability Index Calculation

The burn ability index adopt the format proposed by H.N.Banerjee:

$$LSF = \frac{100 \times CaO}{2.8 \times SiO_2 + 1.65 \times Al_2O_3 + Fe_2O_3} \tag{3.1}$$

$$BF = LSF + 6 \times (SM - 2) - (MgO + K_2O + Na_2O) \tag{3.2}$$

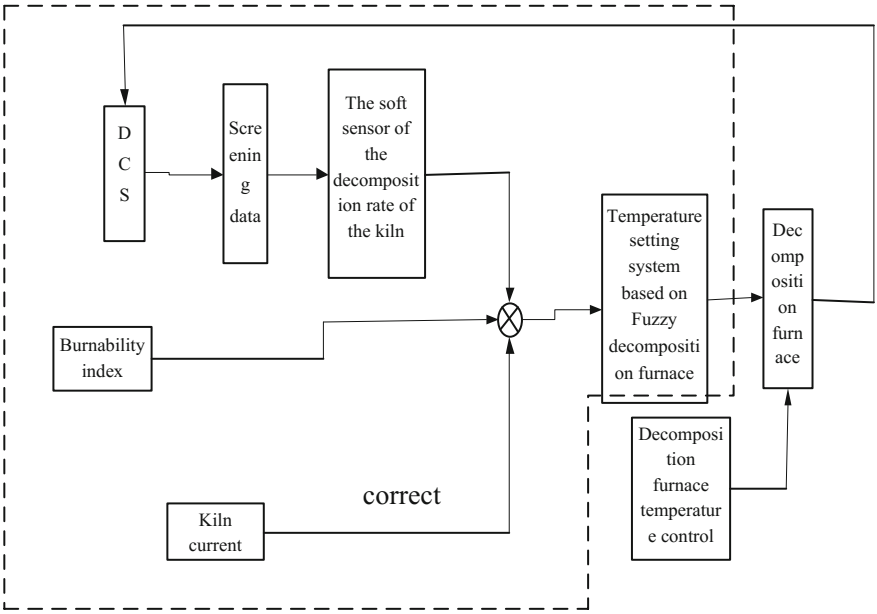

Fig. 2 The block diagram of the control system of the kiln decomposition rate

Among them, BF is the burn ability index.

In the actual production, the three rate values of raw material will be inputted into DCS (once per hour), automatic acquisition, so, we need to change the above formula, using the three rate values of raw materials, the expression will replace the above chemical expression about three rate values

$$LSF = \frac{100 \times [KH \times SM \times (IM + 1) \times 2.8 + 1.65 \times IM + 0.35]}{2.8 \times (IM + 1) + 1.65 \times IM + 1} \tag{3.3}$$

$$BF = LSF + 6 \times (SM - 2) - Q \tag{3.4}$$

the Q is the default value, because of the raw material, the contents of Na_2O, K_2O, MgO are very few, so in this paper, the default value is 2 for all this can instead.

3.2 *The Fuzzy Control System of Decomposition Furnace Temperature Setting*

After completing of online estimation of the decomposition rate and calculation of burn ability index, based on the fuzzy rules, the automatic control of the temperature setting value of the decomposition furnace is realized, and then the automatic

control of the decomposition rate of the kiln is finally realized through the automatic control of the decomposition rate temperature.

3.2.1 Fuzzy Input

In the decomposition rate control system, the burn ability index and the value of decomposition rate as the input of the two-dimensional fuzzy controller to characterize the different raw materials real time decomposition, and defined as D1, D2. D1, D2 both contain 3 fuzzy subsets, in {N, O, P} representation, D1 means {difficult to burn, normal, easy to burn}, D2 means {decomposition low, decomposition normal, decomposition high}. The basic domain sets to [80, 99] and [−1, 1]. In order to ensure that the setting value does not change, the incremental output is used and domain temporary is located [−7, 7]. 5 fuzzy subsets are included, representing [Negative major adjustment, Negative minor adjustment, keep, positive major adjustment, positive minor adjustment].

At the same time, in order to ensure the stability of the control, the value of the setting value should not be changed frequently, so the trapezoidal membership function which is not changed within a certain range and at special points on the fast change is adopted.

In summary, the formulas of decomposition rate membership degree are:

$$f_1(x) = \begin{cases} 1, & 80 \le x \le 89, \\ \frac{90-x}{90-89}, & 89 \le x \le 90, \\ 0 & x \ge 90 \end{cases} \tag{3.5}$$

$$f_1(x) = \begin{cases} 0, & x \le 89, \\ \dfrac{x-89}{90-89} & 89 \le x \le 90 \\ 1, & 90 \le x \le 94, \\ \dfrac{95-x}{95-94} & 94 \le x \le 95 \\ 0 & x \ge 95 \end{cases} \tag{3.6}$$

$$f_1(x) = \begin{cases} 0, & x \le 94, \\ \frac{95-x}{95-94}, & 94 \le x \le 95, \\ 1 & x \ge 95 \end{cases} \tag{3.7}$$

Burn ability of membership formulas are similar to these. The formulas are as follows.

$$f_2(x) = \begin{cases} 1, & x \le -0.5, \\ \frac{-0.3-x}{0.2}, & -0.5 \le x \le -0.3, \\ 0 & x \ge -0.3 \end{cases} \tag{3.8}$$

$$f_2(x) = \begin{cases} 0, & x \leq -0.5, \\ \dfrac{x-(-0.5)}{0.2} & -0.5 \leq x \leq -0.3 \\ 1, & -0.3 \leq x \leq 0.3, \\ \dfrac{0.5-x}{0.2} & 0.3 \leq x \leq 0.5 \\ 0 & x \geq 0.5 \end{cases} \tag{3.9}$$

$$f_2(x) = \begin{cases} 0, & x \leq 0.3, \\ \frac{0.5-x}{0.2}, & 0.3 \leq x \leq 0.5, \\ 1 & x \geq 0.5 \end{cases} \tag{3.10}$$

3.2.2 Fuzzy Rules

According to the experience of the excellent operator and the relevant cement production process, we summary the forms of control rules are as follows: if A and B then C, $f1$ is the fuzzy value for decomposition rate, $f2$ is the fuzzy value of burn ability. The fuzzy handwriting of them respectively correspond to the digital 1, 2, 3, the Settled values of the 5 fuzzy subsets corresponding to the digital 1, 2, 3, 4, 5.

If $f1$ is 1 and $f2$ is 1 then U is 5
If $f1$ is 2 and $f2$ is 1 then U is 3
IF $f1$ is 3 and $f2$ is 1 then U is 2
If $f1$ is 1 and $f2$ is 2 then U is 4
If $f1$ is 2 and $f2$ is 2 then U is 3
If $f1$ is 3 and $f2$ is 2 then U is 2
If $f1$ is 1 and $f2$ is 3 then U is 4
If $f1$ is 2 and $f2$ is 1 then U is 2
If $f1$ is 3 and $f2$ is 3 then U is 1

3.3 The Correction Module Design of the Rotary Kiln Motor

In the actual production, because of the model mismatch, there is a certain degree of deviation in soft measurement of the kiln decomposition rate and fuzzy rules, therefore the kiln motor current is adopted to modify. If the kiln motor current drops, then increases the setting value of decomposition furnace temperature, and vice versa. By analyzing the historical data of cement plant, the kiln motor current about 490 is normal, 470 is lower and 510 is higher.

In the actual production, according to the operation experience, If the kiln motor current is low in long term, this kind of situation is very harmful to the quality of clinker. What is more, operator's operating experience is generally to improve the

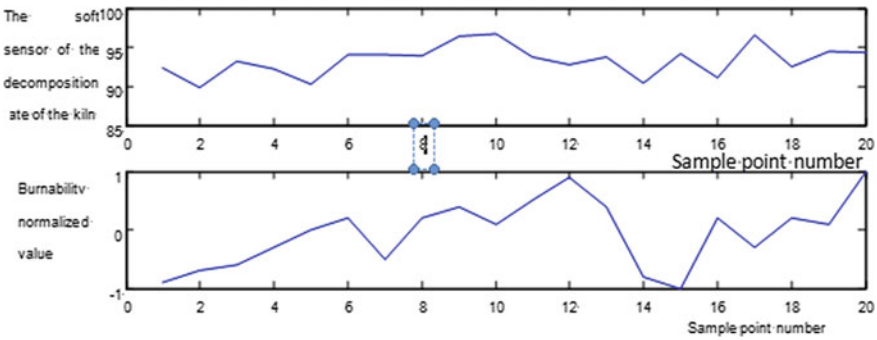

Fig. 3 The kiln decomposition rate and the normalized value of burn ability according to the model prediction

decomposition furnace temperature setting value and increase the decomposition rate. Therefore, when the kiln motor current is low, the temperature of decomposition furnace setting value is increased. Two mean filter is used by kiln motor current, each time is 150 s.

4 Conclusion

4.1 System Simulation

After the design of the main parts of the system, according to the historical data of the cement plant, the setting system of pre-decomposition temperature was validated. According to the normalization of burning resistance and the value of soft measurement of the decomposition rate, the Fig. 3 was obtained.

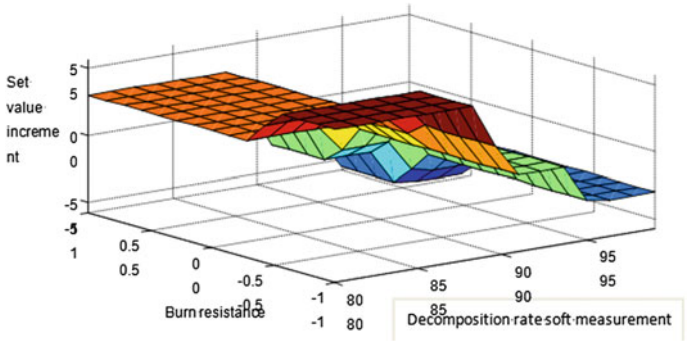

Fig. 4 Three dimensional control chart based on the output of fuzzy controller

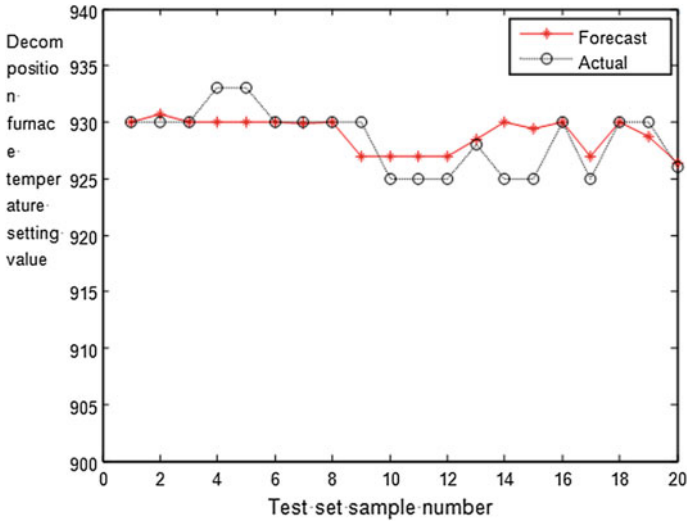

Fig. 5 Comparison of simulation and actual value

According to the design of the fuzzy controller to get three-dimensional graphics, as shown in Fig. 4.

According to the fuzzy output, comparison with actual output is shown in Fig. 5.

As can be seen from the graph, the trend of the system output and operator's manual setting is basically t same. The practicability of the system is verified.

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