Soft Sensor Modeling and Simulation Research of Flotation Cleaned Coal Ash of Slime

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Abstract. Realizes the flotation process cleaned coal ash soft Sensor is the key of flotation process automation. First introduction to least square support vector machines algorithm, subsidiary variable choice research on flotation process cleaned coal ash soft sensor is carried out, reasonable subsidiary variable is selected by experiment, soft sensor accuracy of coal change is proposed, experiment show that model accuracy is sensitive for coal change. This soft sensor model is help to flotation process automatic control.

Keywords: Flotation cleaned coal ash, Least square support vector machines, Subsidiary variable choice, Anthrax fluctuation.

1 Introduction

The flotation process has the serious misalignment, the close coupling and the big lag characteristic, is a physical chemistry synthesis reaction process, the ultimate objective is achieving the Quality assurance of flotation process product and the production rate maximization. Except development and the optimization in the flotation process equipment and the craft aspect, the flotation process automation is also realizes the above goal important condition and the method, the solution flotation process cleaned coal ash real-time examination is a key technology of realizing the slime flotation process automation, many domestic and foreign scholars launched study and have made certain progress and the progress [1, 2, 3]. Overseas have researched the measuring appliance of flotation cleaned coal ash examination, but because of the high price limits its application in the coal preparation plant. The domestic use the same principle the development measuring appliance, because of reliability, precision and security causes to be unable to promote in the coal preparation plant. The soft sensor theory and the technical rapid development and the application have provided the new mentality for the slime flotation cleaned coal ash examination. The soft sensor modeling based on the flotation process parameter Involves to the metalliferous ore flotation process present domestic and foreign research, the slime flotation process relatively are few. Based on support of the statistics theory ,vector return modeling technology by it to the small sample's serviceability, the most superior of overall situation and good model pan-ability becomes a kind of important modeling method in the soft sensor development, Natural can provide the worth trusted theory and the technical support for the flotation

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cleaned coal ash soft sensor . Last square support vector machines operating speed to be quick, becomes the good technology which the statistics theory of learning and the support vector machines algorithm realized and obtained many research.

The paper take least square support vector machines modeling technology as the instruction, launches the subsidiary variable of the slime flotation cleaned coal ash soft sensor ,choices research and changes in view of the anthrax the soft sensor model the compatible research, provides the beneficial exploration and reference for the flotation cleaned coal ash soft sensor modeling.

2 Least Square Support Vector Machines Modeling Principle [4,5]

LS-SVM was increased the erroneous sum of squares item in the standard SVM objective function foundation , that between least square support vector machines (LS-SVM) and support vector machines (SVM) ,the main diversity is square item of errors as loss function, is not the insensitive loss function as the loss function. This then may transform the inequality constraint condition the equality constraint condition. In nonlinear system, Regards as the misalignment regression function is:

$$f(x) = w^T \phi(x) + b \tag{1}$$

And : $x \in R^n$, $y \in R$,

misalignment function $\phi(\cdot)$: $R^n \to R^{n_k}$.

The input space data will map the high Uygur feature space through the mapping function. For assigns the training data set $\{x_k, y_k\}_{k=1}^N$, LS-SVM May define the following optimized question, γ is regularization parameter.

$$\min_{w,b,e} J(w,e) = \frac{1}{2} w^T w + \gamma \frac{1}{2} \sum_{k=1}^{N} e_k^2 \tag{2}$$

$s.t.$ $y_k = w^T \cdot \phi(x_k) + b + e_k$, k=1,,,n

Assigns the Lagrange function is:

$$L = J - \sum_{K=1}^{N} a_k [w^T \cdot \phi(x_k) + b + e_k - y_k] \tag{3}$$

In the above equation α is the Lagrange multiplier.

Again based on the KTT condition:

$$\begin{aligned} &\frac{\partial L}{\partial w} = 0 \to w = \sum_{k=1}^{N} a_k \phi(x_k) \\ &\frac{\partial L}{\partial b} = 0 \to \sum_{k=1}^{N} a_k = 0 \\ &\frac{\partial L}{\partial e_k} = 0 \to a_k = \gamma e_k \\ &\frac{\partial L}{\partial a_k} = 0 \to w^T \cdot \phi(x_k) + b + e_k - y_k = 0 \end{aligned} \tag{4}$$

For K=1,…,N, Eliminates w and e, then obtains the following equation equality:

$$\begin{bmatrix} 0 & 1^T \\ 1 & K+\gamma^{-1}I \end{bmatrix} \begin{bmatrix} b \\ a \end{bmatrix} = \begin{bmatrix} 0 \\ Y \end{bmatrix} \tag{5}$$

In the equation equality:

$$1=[1,...,1]^T, Y=[y_{1,...,}y_N]^T, a=[a_{1,...,}a_N]^T \tag{6}$$

K is a Phalanx, Its i line of j row element is

$$K_{ij}=\phi(x_i)^T\phi(x_j)=k(x_i,x_j) \tag{7}$$

k () is Kernel function. Further solves coefficient b and a through the use least squares method, finally obtained the LS-SVM model forecast output is:

$$y(x)=\sum_{k=1}^{N}a_k\phi(x)^T\phi(x_k)+b=\sum_{k=1}^{N}a_k k(x,x_k)+b \tag{8}$$

3 Experimental Research on Flotation Process Cleaned Coal Ash Soft Sensor Modeling Subsidiary Variable Selection

3.1 Soft Sensor Modeling Performance Evaluation

For a forecast model, the key is obtaining the predicted value by the good effect, the evaluating indicator uses for to appraise the forecast model fit and unfit quality. The paper uses the mean square root error to weigh the system deviation. If the mean square root relative error value is small, the showing predicted value depending on the approximate real value, the forecast effect is good, and otherwise the showing forecast effect is bad.

The mean square root error definition is:

$$MSE=\frac{1}{l-1}(\sum_{i=1}^{l}|y_i-y_i^*|^2) \tag{9}$$

Least square support vector machines algorithm to the system model parameter choice, the paper uses confirms (cross-validation) to make the parameter choice adjustment alternately. The cross-validation's basic philosophy is: Divides sample collection into two subsets oneself, with a group (training regulations) come the modeling, another group (test collection) uses in examining, then appraises the forecast performance according to the check result, and adjusts the related parameter, afterward carries on the same training and the alignment procedure again. When pan-wrong achieves the ideal value, and then obtains the corresponding parameter.

3.2 LS-SVM Model Structure Establishment and Simulation Confirmation

Subsidiary variable's determination is the question which the soft sensor modeling first needs to solve. The determination suitable subsidiary variable can guarantee that the soft sensor model can obtain to leads the variable the correct estimate. set

condition flotation experiment data of the Zhangcun slime to divide into two kinds stochastically, kind of achievement training regulations, another kind of achievement test collection , carries on least square support vector machines soft sensor modeling, that uses the training regulations data to carry on the training, uses the test collection data to carry on the simulation contrast, finally obtains the good suitable flotation cleaned coal ash soft sensor model, then provides the basis for next step industry the modeling and simulation.

Table 1. Zhangcun Soft-Sensing Model Data Acquisition

Collectors	Frothers	Concent-ration	tailings Ash	Cleaned coal ash
1000	200	40	38.65	8.28
1000	200	70	52.38	8.96
1000	500	40	60.05	8.85
1000	500	60	66.74	9.72
1000	200	60	47.75	8.92
800	120	60	30.00	7.96
800	200	50	35.81	8.25
800	200	60	44.09	8.97
800	400	60	63.31	9.30
1000	400	60	65.28	9.13
1000	120	60	29.79	8.01
1000	500	70	68.55	10.32
800	400	50	58.93	8.85
1000	200	60	47.75	8.92
1000	200	50	44.39	8.64
1000	500	50	63.86	9.43
1000	300	60	56.65	9.06
900	120	60	29.92	7.98

Basis to flotation cleaned coal ash influence first uses collector and frother quantities, Concentration, the air input of Zhangcun flotation process data sheet Tab.1 as subsidiary variable, the cleaned coal ash as the leading variable carries on the LS-SVM simulation. And the first 12 data take the training regulations, latter 6 achievement as test collection, The optimization adjusts gam and the sig2 parameter value, gam parameter is Regularization parameter, is controls to the wrong assignment sample penalty degree adjustable parameter, sig2 parameter is RBF Kernel parameter, is controls bandwidth of “RBF_kernel”. Penalty factor C and the Kernel parameters σ of standard SVM (radial direction base nuclear function) correspond. (In the later simulation the parameter significance is the same, the behind simulation no longer specially stated), Simulation result as shown in Fig. 1.With Tab.1, collector, frothers, the Concentration, the tail coal ash as the subsidiary variable carries on modeling with LS-SVM, and the first 12 data take the training regulations, latter 6 achievement test collection, Simulation result as shown in Fig.2.

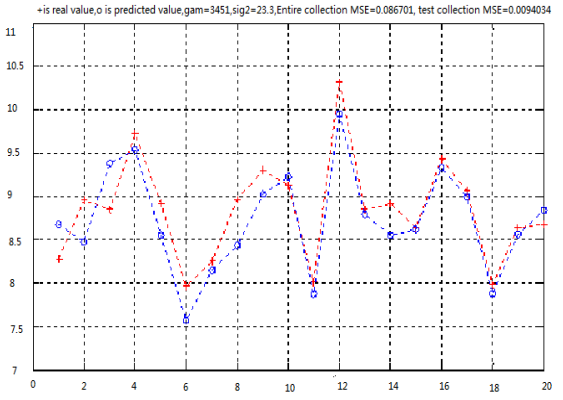

Fig. 1. Simulation about Collector, Frother and Concentration as Auxiliary Variable

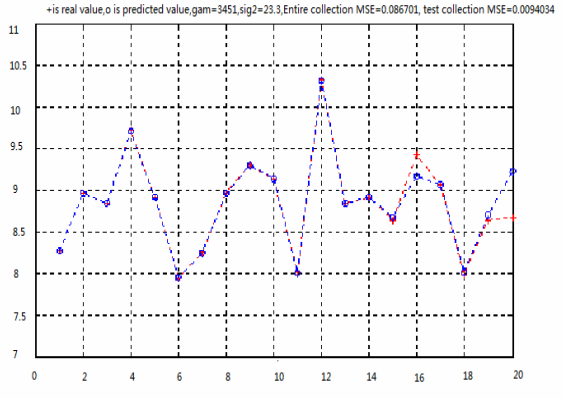

Fig. 2. Simulation about Collector, Frother, Concentration and Flotation Tailings Ash as Auxiliary Variable

Contrasts the above two charts to be possible to see, although Fig.1 tests the collection error slightly is smaller than Fig.2 test collection error, but its training regulations error actually compared to Fig.2 existence big error, this will cause its entire type collection error to be higher than Fig.2 entire type collection error directly. Between this phenomenon and the test collection data existence error may be possible has certain relations, therefore fit and unfit quality of evaluation model must make a balance at the test collection error and the entire type collection error two aspects. In summary, Fig.2 soft sensor modeling must surpass Fig.1. This also fully explained that in the soft sensor modeling choice of subsidiary variable has the very important function to the model return precision. May also see from the above two chart's contrast: The choice process observed value to leads the variable the return precision to be limited merely, investigates its reason to lie in lacks the separation result the attribute parameter. What because modeling forecast is the cleaned coal ash, the

choice of nature subsidiary variable concentrates the flotation process tail coal quality which and the leading variable is closely linked to come up.

Regardless of the latter test collection error and entire type collection error all good in the former, soft sensor modeling surpass the former. Therefore, the subsidiary variable increases with the flotation process product nature related parameter are helpful to the enhancement return precision and the return stable uniformity. The different origin coal sample's empirical datum simulation result indicated: under the laboratory condition, uses the collector quantity, the frother dosage, the concentration, the tail coal ash pattern input to be possible to obtain the high model precision, namely the tail coal ash is very big to the soft sensor modeling forecast precision influence. Therefore may draw the conclusion: use the appropriate flotation tail coal ash to have the relevant sensor enormous to increase the flotation cleaned coal ash soft sensor modeling precision and extrapolation ability, in uses actually on flotation tail coal examination sensor, is the electro-optical principle sensor, by this achievement subsidiary variable, may obtain is similar to the tail coal ash test effect.

4 Modeling Accuracy Research on Coal Property Change

4.1 Model Accuracy Research on Different Mine Pit Coal

Under the laboratory condition, use the collectors quantity, the frothers dosage, the concentration, the tail coal ash be pattern's input, use the Zhangcun flotation process data as training set, separately use coal sludge flotation process data of mine 5# and 10# as the test set; after the LS-SVM modeling, separately examines two kind of typical operating modes, the LS-SVM model whether to be suitable and through the optimized model whether model parameter to be suitable.

The Zhangcun flotation process empirical datum as the training set- mine 5# slime flotation process empirical datum as the test set:

From the contrast of simulation experiments may see, if the coal property changes, regardless of how to adjust parameter: gam and the sig2 is unable to correctly predict the concentrations ash so that we must reject the old training set, establishes in view of the concrete coal property training set again, then adjust and optimize the new parameter in order to be able to satisfy the control system's request.

4.2 Model Accuracy Research on Different Coal Bed

Under the laboratory condition, uses the collectors quantity, the frothers dosage, the Concentration, the tailings ash be pattern's input, makes the training set by some mine 5# condition flotation process data, takes the test set with some mine 10# condition flotation process data, and optimizes and adjusts parameter: gam and sig2 with the LS-SVM modeling, with the optimized model examines compatibility of the identical mine pit different coal bed’s coal sludge to the soft sensor modeling, that whether does the old model under the identical mine pit different coal bed condition can still maintain the same forecast precision.

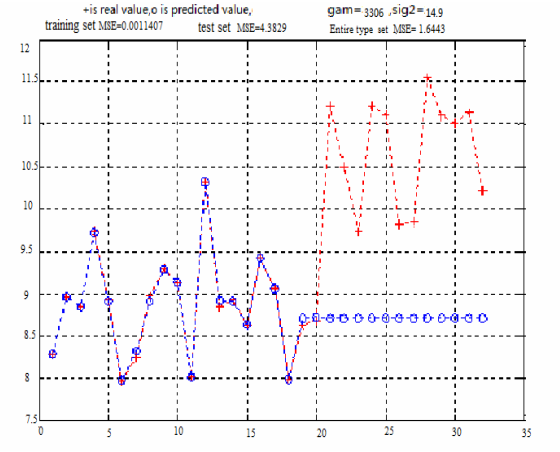

Fig. 3. Zhangcun(training set)-Mine 5#(test set)Simulation (original parameter)

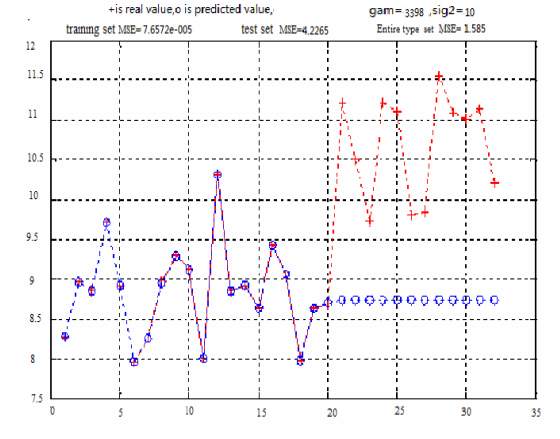

Fig. 4. Zhangcun(training set)- Mine 5#(test set) Simulation(parameter optimization)

The simulation result indicates that if the mining coal bed changes, merely depends adjusting parameter: gam and the sig2 is unable to achieve the requesting forecast precision of soft sensor modeling, therefore must reject the old training set, uses the new training set to carry on the training can satisfy control system's request.

The empirical datum research which paper used indicated: Different coal originates in the different mine pit as well as the coal of identical mine pit different coal bed ,needs to gather the data to establish the new soft sensor modeling, which can guarantee the model's forecasting precision. When design flotation concentrate's soft measurement system should consider that increases function that under the different coal situation the model to cut as well as increases the new soft sensor modeling to adapt the coal property's change.

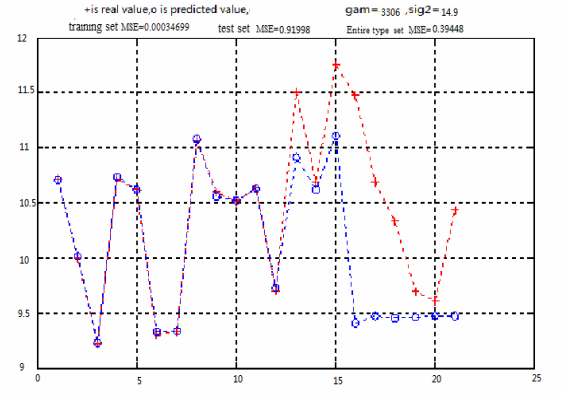

Fig. 5. Mine 5#(training set)-Mine 10#(test set) Simulation(original parameter)

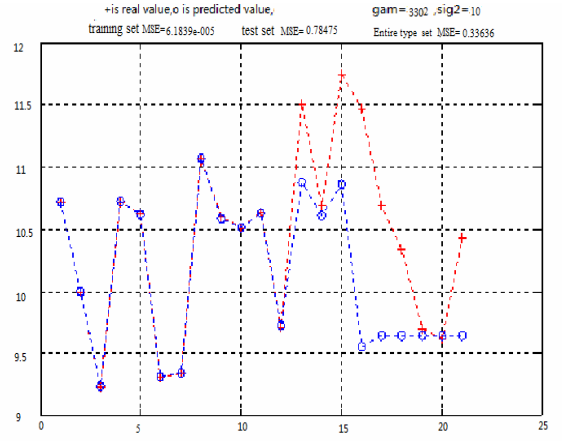

Fig. 6. Mine 5# (training set)-Mine 10#(test set) Simulation

5 Conclusion

Uses the different coal flotation process data, draws the conclusion through the simulation contrast: The collector quantity, the frother dosage, the density, the tailing's ash takes the subsidiary variable to be able to guarantee the flotation concentrate's ash model's forecasting precision. The simulation result that different coal influences the flotation cleaned ash forecast precision indicated: The different coal bed and the different coal to forecasting precious has very tremendous influence, in the scene soft sensor implementation it should increases entering the float coal archery target choice and the corresponding model cut mechanism, satisfies the scene to the flotation process ash forecast precision request. The simulation indicated that the LS-SVM soft sensor modeling may be used in the concentrate ash soft sensor modeling algorithm.

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