# Real-time analysis and online prediction of the process parameters in the process of a dense medium separation

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**Abstract:** The process parameters of the dense medium separation used to be predicted in the design process of a coal preparation plant. The data calculated in a month synthesizing and detected by a detectors is only that after the event. A online prediction system for the process parameters of dense medium separation system were developed. The system could accomplish the calculation of coal preparation recovery rates and productivities in real-time, the prediction of the density composition of the feeded raw coal, the concentrate yield, the efficiency and the density of the dense medium separation on line. The achieved parametes could be transmitted to the control system as the given control limite index. The system has been used in the product line efficaciously.

**Key words:** coal preparation plant; dense medium separation; real-time analysis; online prediction; hybrid programming

## 0 Introduction

The dense medium separation process has been used widely. So the proper control of the process is the key to improve the operation efficiency. Numerous scholars have been worked on the analyzing, predicting, [1~2] and automatic control of the dense medium separation process [3-5]. However, the process used to be accomplished based on the manual given density [6-7], neither the feed property nor the other process parameters were taken into account. The process parameters of the dense medium separation used to be predicted in the design process of a coal preparation plant. The data calculated in a month synthesizing and detected by a detector is only that after the event. After having summarized the previous experience, in this article, For the control of the heavy media preparation process, a real time analysis and online separation effect prediction system was developed, which is designed to provide reliable data base for auto-controlment and comprehensive references for the plant production management.

## 1 The Design skeleton of the System

The system has two basic functions: Real-time data collection and analysis, that is collecting the online and historical data in the dense medium separation process for analysis and forecast; real-time calculation and on-line prediction for process parameters, including the density composition of raw coals, concentrate yield, efficiency and separation density, etc. which can be provided as the basis for production and management.

Figure 1 is the system structure. The system is logically divided into three parts: The first is data collection, mainly focusing on real-time data detection and remote data transmission; the second is data analysis, after the completion of data collection, the system will fit curves, calculate data and predict parameters though interactive technology of Delphi and Matlab. The third is display which will accomplish the data transmission and Web display based on B/S structure part by using XML and Flash technology.

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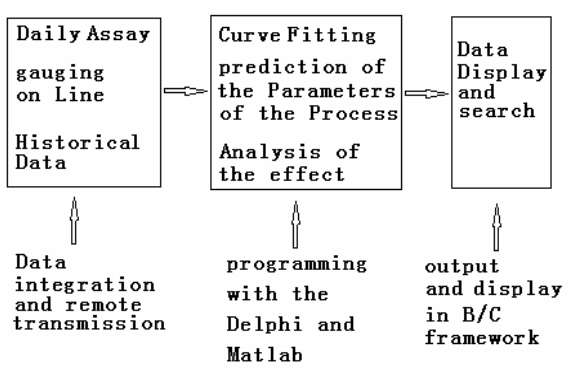



Fig. 1 structural of system

# 2 The implementation procedure of System's Function

## 2.1 Basic Data Acquisition

Basic data includes historical data and real-time data. Historical data is obtained from the historical database according to the requirement, and real-time data is detected instantaneously by the various sensors installed in the dense medium separation system. In addition, some data got through manual operation like the fast ash and fast water will be input into the system through the interface. The input interface is programmed with Delphi and equipped with a data dictionary which make it easy to operate. The date can be immediately transmitted to the real-time data analysis and forecasting module through network.

## 2.2 Online Prediction of the Process Parameters

The system may predict the density components of a feed coal, the concentrate yield, the separation efficiency and the density, etc. The basic means is to calculate the predictive value by using a known separation condition and a feed characteristic, in which the curve fitting is implemented through Matlab and the rest is programmed with Delphi.

### 2.2.1 Prediction on Density Composition of Feed Raw Coal

The feed raw coal data is the basis for the following prediction and calculation. In general, the raw coal data is analysed per month in a coal preparation plant. However, for the density composition of a coal is changing at any time, so the real-time prediction should be conducted for a raw coal data so as to make an actual prediction for production status.

The way and steps to predict the feed raw coal data in the system is as follows:

(1) Prepare the representative latest month comprehensive data of raw coal;

(2) Select the appropriate ash basis for prediction basis;

(3) Get the forecasted data of the current feed raw coal's density composition according to the previous calculation.

The predicted density composition of raw coal with time-varying:

$$\Gamma_i(t) = y_i(t, \delta_i, A_y) \quad (1)$$

$$\mathrm{A}_i(t) = a_i(t, \delta_i, A_y) \quad (2)$$

t— calculating time point，s； $\delta_i$ —No.i density interval； $A_y$ — row coal ash at time t; $y_i(t, \delta_i, A_y)$ — predicted row coal yield of $\delta_i$ at time t with $A_y$； $a_i(t, \delta_i, A_y)$ — predicted row coal ash of $\delta_i$ at time t with $A_y$。

The prediction information for raw coal can be used not only to calculate other index in this system but also to provide more reliable guide to automatic control system.

### 2.2.2 Simulation of the Distribution Curve

Product structure prediction includes yield, ash etc. The prediction is based on the character that distribution curve has little connection with the density composition of the raw coal. When the coal density compositions and required clean coal ash change, the density-level distribution rate can be obtained predict by moving distribution curve in parallel and the light and heavy product yields and ash be predicted by using raw coal washability curve and the density distribution rate.

The key to predict product structure under a certain separation density is to obtain the distribution rate of each density level. Empirical formula can be used to calculate distribution rate of each density level in a separation density, which is much more convenient. However, the distribution rate of the empirical formula is more ideal than the actual one, so the system uses the actual distribution curve model. Distribution curve are drawn by fitting or interpolation in Matlab, and then the results are imported into the program in Delphi to complete the forecast.

The biggest problem is how to shift distribution curve as the change of the separation density when the actual distribution curve was used in the product structure prediction. According to the standards promulgated by the original Ministry of Coal Industry, the probable error E keeps still for the heavy medium coal preparation, when the density changes. A new curve could be made only by moving coordinate of the density, which is shown in Figure 2.

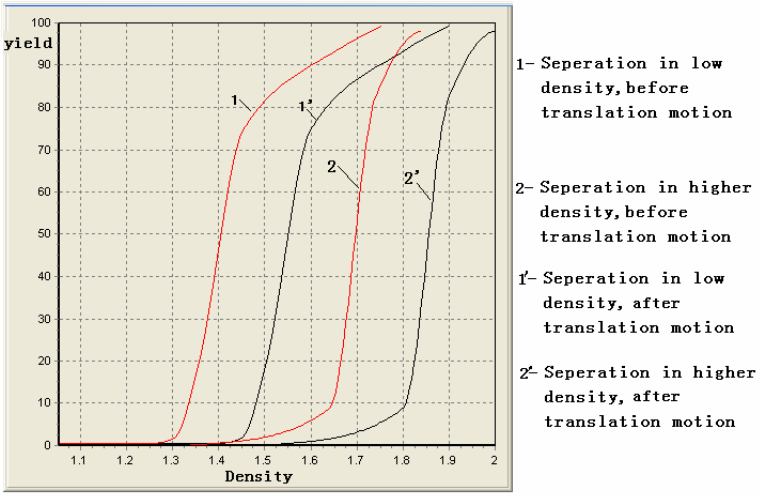



Figure 2 distribution curve before and after translating

The low-density segment distribution curve equation got after moving coordinate:

$$\varepsilon_1 = f_1(\delta, t) \qquad (3)$$

High-density segment distribution curve equation:

$$\varepsilon_2 = f_2(\delta, t) \qquad (4)$$

In equation (3) and (4), $\varepsilon_1$ is the distribution rate for the low-density segment, $\varepsilon_2$ is the distribution rate for high-density segment, $\delta$ the density of the sorted coals, t is the time point at which the prediction happens.

Set $\delta_i$ (i = 1,2, ..., n) as the point i of density coordinates, the corresponding low-density distribution rate is $f_1(\delta_i, t)$, the high-density distribution rate is $f_2(\delta_i, t)$.

### 2.2.3 Process Parameters Prediction

This part of forecast parameters includes separation density, product ash, separating efficiency, and the amount of coal losed in middling.

Separation density prediction is based on the prediction of the feed raw coal quality. As mentioned above, the real-time coal washability curve can be obtained according to the real-time forecasted row coal data. Then theoretical separation density and yield values can be derived through the fitting formula. Using the translating the distribution curve and feed coal washability curve the predicted actual product parameters can be acquired.

For example the clean coal yield of the density interval i at time t could be obtained by moving in parallel the distribution curve and feed coal washability curve

$$\Gamma_{Ji}(t) = Y_I \bullet (1-\varepsilon_1) = y_i(t,\delta_i,A_y) \bullet [1- f_1(\delta_i,t)] \quad (5)$$

The total yield of a product could be obtained by summing all of that of each density intervals, For example, the predictive value of losing coal in middlings is the integration as follows:

$$\text{The predicted yield middling } = \int_{\delta_s}^{\delta_t} (1-\Gamma_{ji}(t)) \bullet [1- f_2(\delta_i,t)] d\delta \quad (6)$$

$\delta_s$ is the predicted separation density; $\delta t$ is the upper density which should be similar to the density of waste rock; $(1-\Gamma_{ji}(t))$ is feed of high-density segment that subtracted clean coal from the row coal. ( $f_2(\delta_i,t)$ ) is the fitted high-density segment distribution curve equation.

## 2.3 Real-time Analysis of the Dense Medium Separation Process

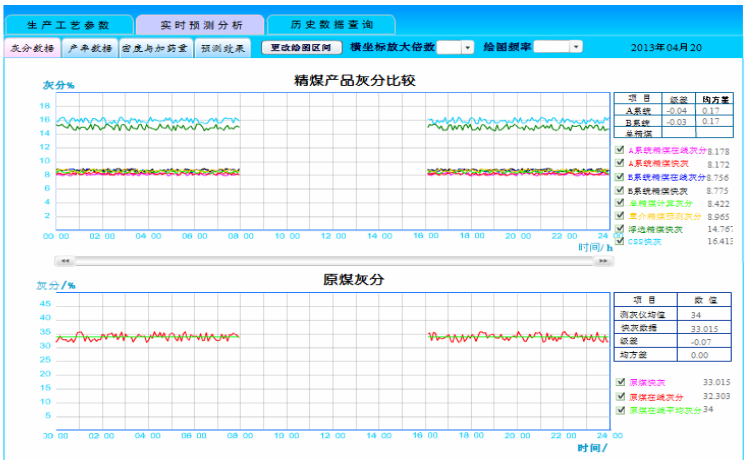
The real-time analysis of the separation performance and the process status of the dense medium separation could be accomplished with the help of the predicted parameters and the scanned data on line. The management index and the result of process analyzing could be calculated directly or indirectly. The control parameters of other steps in production process also could be obtained. For instance, the required index are theoretical and actual values of the clean coal yield, productivity and loss coal in the middling ,etc. in the dense medium separation system. The contents to be analysed in real-time are listed in Table 1.

Table 1 The contents of real-time analysis based on the predicted scanned data on line

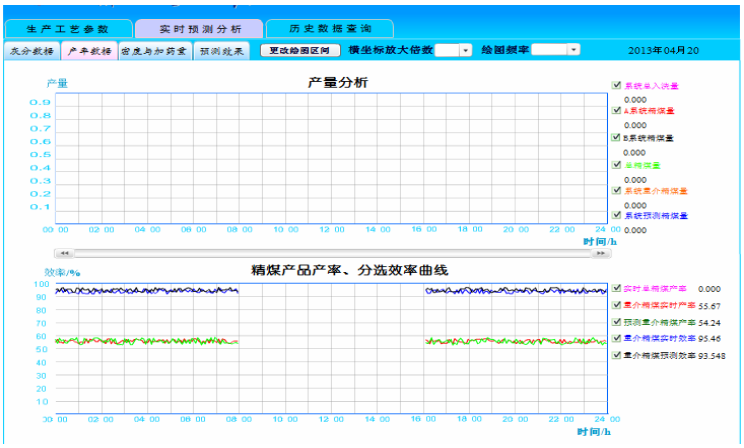
| *content* | *Basis data* | *purpose* |
|---|---|---|
| Compare the scanned ash of row coal and clean coal in real time to the assay ash | Instantaneous value and ever valve on line, assay value | Calculating error between them, adjust detector and scan value |
| Calculate the yield of clean coal in real time | Feed and clean coal quantity from electronic balance on line | As the value of reference and contrast |
| Calculate the ash of +0.5mm feed | Adjusted scan value | Predicting basis of feed property |
| Predict the density composition of the feed at time t | Adjusted scan ash value of feed, the density composition gotten through test | As the predicting basis for all the process parameters |
| Predict the washability and separation density | Predicted the density composition of the feed at the moment | As the basis of control and analysis |
| Predict the yield and ash of the products | Predicted the density composition of the feed at the moment, partition curve | |
| Compare of the yield of clean coal | The yield of online, predicted actual, and predicted theoretical value | Confirm the serviceability of the predicted process parameters and the method |
| Compare of the Ash of feed and products | Instantaneous, ever, and predicted value on line, assay value | |
| Compare of the Efficiency of separation | actual, theoretical, and predicted value | |
| Compare of the Separation density | Instantaneous detected, tested, predicted actual, and predicted theoretical value | |

## 2.4 The System Output Interface for Real-time Analysis Results

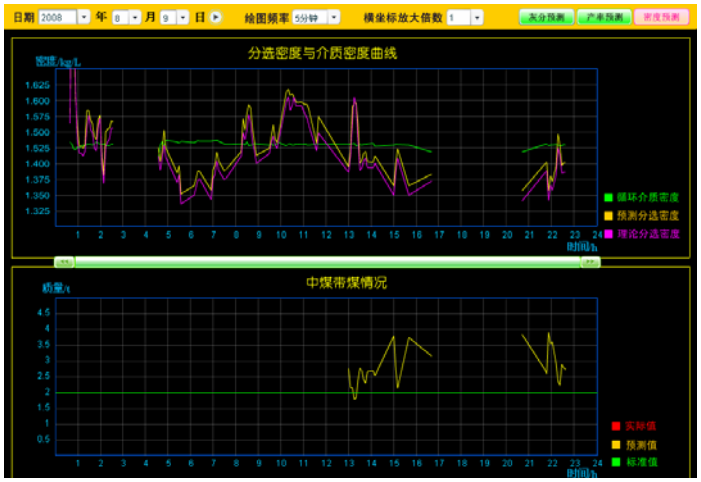
Real-time prediction results could be express by the curves. The output interface in form of web pages includes several plates: (1) The real-time display and comparison of fast ash, instantaneous raw and clean coal ash, average clean coal ash in a spell; (2) The real-time display of raw coal, clean coal quantity and production rates; (3) The display and comparison of the real-time clean coal yield, forecast yield and theoretical yield; (4) The display and comparison of the real-time efficiency and forecast efficiency in the dense medium process; (5) The real-time display and comparison of the circulating medium density, theoretical separation density and predicted separation density in the dense medium separation system; (6) The real-time display and comparison of the actual value, predicted value and standard value of loss coal in the middlings. That are shown in the flowing figures.




（a）




(b)




(c)

Fig. 3 Output panel of system

a-curves of cleaned coal ash and quality; b-curves of cleaned coal yield and separation efficiency; c-curves of separation density and middlings attachment

## 3 Conclusion

In this paper, a software system is introduced used to real-time analysis and online forecast for the dense medium separation performance, which could calculate the recovery and production rate, forecast the density composition of raw coal, clean coal yield, efficiency, and separation density, etc. instantly during operating of the dense medium process . The system has the following characteristics:

The function of the system could analysis and comparison of the Real-time detection data, theoretical data and forecast data. The results provide scientific, fast, reliable and comprehensive basis for production management, decision-making and automatic control system.

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# 重介分选工艺参数的实时分析与在线预测

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**摘要：**重介分选过程的工艺参数，一直以来只有在设计过程中进行预测，在月综合时进行计算和在线检测的数据都是事后数据，实时的重介工艺参数预测方法一直没有研究。为实现实时控制重介分选过程，研究了重介生产参数在线预测与系统。该系统可以实时进行选煤厂分选系统的产品产率和分选效率，在线预测入选原煤的密度组成、产品产率和分选密度。计算的结果还可以传递给控制系统，作为实时给定的控制参数。系统在现场使用得到很好的效果。

**关键词：**选煤厂；重介分选；实时分析；在线预测
**中图分类号：**TD 9