APPLICATION OF BIG DATA IN OPTIMIZATION OF BLAST FURNACE OPERATION *

Wang Gang1
Wang Jing-song2
Xie Hao3
Yan Xin4

Abstract
Blast furnace conditions are influenced by hundreds ofraw materials and operation-related factors in a very complicated way. The traditional operation of a blast furnace relies on experience, but when there are many factors changing frequently and simultaneously, there is a coupling effect among the factors. The blast furnace conditions are likely to fluctuate or even become abnormal, and it is difficult to find the right way of relying on people experience. In this paper, Big Data technology is used to analyze the matching relationship between raw materials, operation and blast furnace conditions. Cluster analysis, maincomponent analysis, regression analysis and other Big Data analysis are carried out to find out the rules by which the raw materials and operation-related factors influence the blast furnace conditions, and the orientation to which the blast furnace operation optimization shall be adjusted. It has been applied to a 5000m3 class blast furnace in China. After the optimization, the blast furnace has been operating with a coefficient of productivityof the blast furnace of 2.2t/m3d increased from 1.2t/m3d, fuel ratio 525kg/t decreased from 580kg/t, out of the abnormal conditions, with good production targets.
Keywords: big data; blast furnace; operation optimization.

[1] *Engineer，Ironmaking Department，CISDI Engineering Co., Ltd. Chongqing，China*
[2] *Engineer，Ironmaking Department，CISDI Engineering Co., Ltd. Chongqing，China*
[3] *Engineer，Ironmaking Department，CISDI Engineering Co., Ltd. Chongqing，China*
[4] *Engineer，Ironmaking Department，CISDI Engineering Co., Ltd. Chongqing，China.*

1 PREFACE

Comprehensive judgment is usually required to figure out the best operation mode to operate a blast furnace with high efficiency, stability and low cokeconsumption according to the conditions of raw materials, fuels and the characteristics of the blast furnace. Operators of a traditional blast furnace, based on their experience, can make adjustments to the operations according to the changing tendency of raw materials and fuels, thus avoiding the abnormal blast furnace conditions while maintaining thestableblast furnace operation. However, if the changing factors in the conditions of raw materials and fuels are increased, or the changing frequency is increased, the difficulty of making adjustments will be enlarged in multiples. First, it's hard to define the amount of the adjustment. If even the experience can indicate the clear orientation to the adjustments, it's still difficult to determine the specific amount of the adjustment as the amount of influence is dynamically changing under different time and conditions. Secondly, it's hard to time the adjustments. This is because the lag cycles of influences from various factors are changing dynamically, not consistent, very difficult for the operators to judge accurately according to their experiences. This applies to big blast furnaces in particular. In addition to the conventional adjustments, full considerations have to be given to the effect of inert to the big blast furnaces as they usually have a relatively big "inert". All of these are much challenging to the operators of the blast furnaces. As a matter of fact, every year in the world a lot of big blast furnaces are in abnormal conditions, experimentinglow coefficient of utilization, high fuel ratio, each resulting in an economic loss up to hundred million US dollars per year.
With the development of IT and artificial intelligence technology in recent years, Big Data has been expanded and applied to sectors as e-commerce, logistics, medical care, etc. So far, Big Data has not yet found its extensive and in-depth applications in iron & steel industry, especially in the ironmaking operation. There are two main reasons behind. First, blast furnace ironmaking process is highly complicated, making it difficult establishing learning and prediction modeling relying on Big Data. Secondly, the ironmaking operation data, as industrial process data, have some room for improvements in terms of timeliness, completeness and accuracy, due to the weakness in the accuracy of measuring instruments and the rationality of process layout.
To tackle the abovementioned issues, some engineering companies in China oriented to iron & steel industry have been engaged in making process design, tappingoperation and Big Data fuse, and have developed ironmaking Big Data platform based on Big Data analyses and Big Data analysis system. They can provide powerful technological safeguard for blast furnaces to adapt to variations in the conditions of raw materials and fuels, avoid abnormal blast furnace conditions and optimize the blast furnace operation, marking an important step forward to intelligent ironmaking operation.

2 DEVELOPMENT

Every year millions sets of data are generated by blast furnaces in operation. These data, if utilized effectively, are very precious to realize deep optimization of blast furnace operation, deep TQCM implementation of steel producers. But, a huge number of data were let go because many of the blast furnaces have not been equipped with data acquisition and storage systems. In order to obtain complete, accurate and fast data, an ironmaking Big Data platform has been developed, which can support effectively Big Data mining and intelligent analysis by making systemic research and development in the two dimensions: meeting the process requirements and optimizing the system architecture. The process composition and data flow relations are illustrated in Figure 1 below.

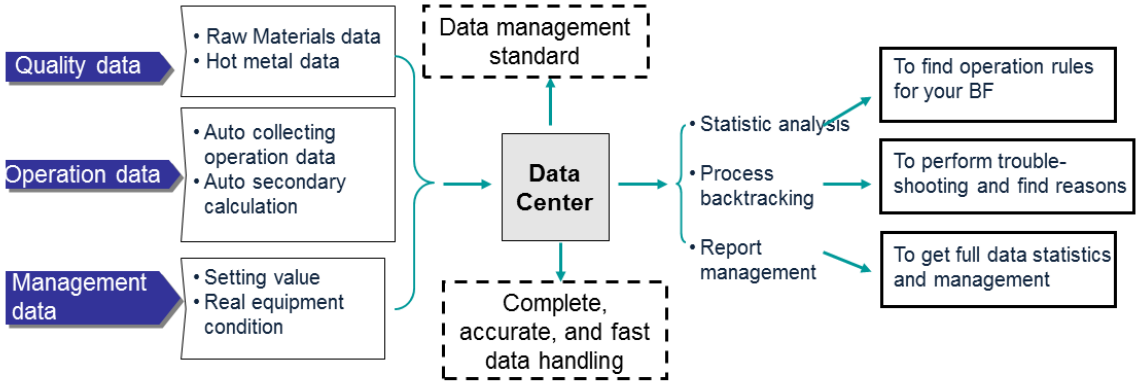

Fig. 1 Coverage of Big Data Platformand Data Correlation

The ironmaking Big Data platform performs the following functions:

1) Achieve systematic, automatic data management by Total Management and storage of ironmaking data;

2) Structure, de-noise and store the data as per the frequency and type required from data mining and intelligent modeling to adjust the Big Data analysis and mining;

3) Realize complete, accurate tracking and matching of ironmaking mass flow, information flow and energy flow.

3 IRONMAKING BIG DATA ANALYSIS SYSTEM

On the ironmaking Big Data platform, deep learning mathematic models have been built by using different Big Data analytic procedures including neural net, genetic algorithm, ant colony algorithm, cluster analysis, multiple regression, time series analysis, etc. to analyze the rules by which the conditions of raw materials and fuels, operating data influence the blast furnace conditions, to establish dynamic prediction and feedback models, calculate the orientations to optimization of blast furnace operation and the amount of quantitative adjustment. At present the system has three core functions: intelligent diagnosis and analysis of blast furnace conditions, optimization and analysis of blast furnace condition indicators and dynamic management of blast furnace critical data reference values. It is able to serve as a strong support for blast furnaces to achieve optimization of operation and improvements of condition indicators.

3.1 Intelligent Diagnosis and Analysis of Blast Furnace Conditions

The intelligent diagnosis and analysis of blast furnace conditions include two parts: daily diagnosis and analysis of blast furnace conditions, and early warning of special conditions of blast furnace.

1) Daily Diagnosis and Analysis of Blast Furnace Conditions

By daily evaluation and analysis of the overall blast furnace conditions, the important parameters of the blast furnace conditions are weighted according to the weight properties to obtain the results of the overall blast furnace conditions, and assess the current blast furnace conditions in a macroscopic way. It allows the senior managers to easily gain timely knowledge about the overall blast furnace conditions. The components of the blast furnace conditions include: raw materials condition, blast furnace hearth condition, tapping condition, burden condition, gas flow distribution, operational profile, etc.

Meanwhile, variations of all the factors causing fluctuations of the components of the blast furnace conditions are tracked and the correlations thereof are listed in order to identify the major conflicts so as to facilitate the operators to solve the problems in time.

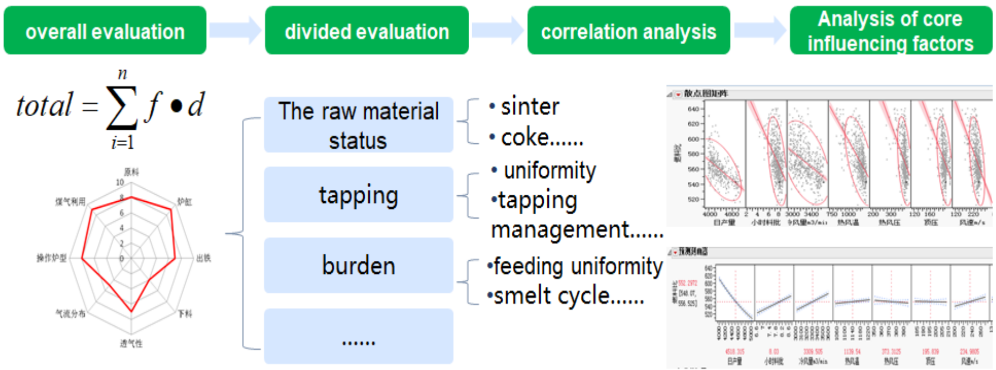

Fig.2Daily diagnosis and analysis of blast furnace conditions

2) Early Warning of Special Conditions of Blast Furnace

By integration data analysis, a surface features system representing the special blast furnace conditions is established to be the scientific support for making unified judgment and conclusions and serve as early warning as well.

Taking into account the ironmaking theory and experts' experience, all the data related to the special blast furnace conditions are analyzed in real time to judge if any of the special blast furnace conditions appear scientifically according to the changes of the data and take scientific and precise measures in advance to avoid abnormal special blast furnace conditions.

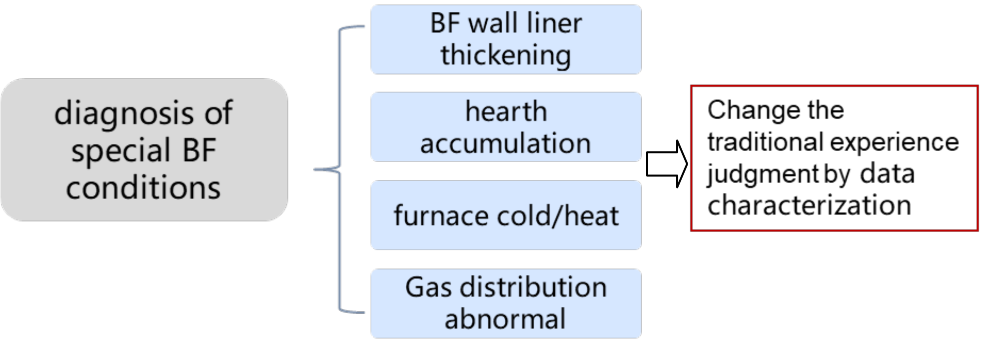

Fig. 3 Diagnosis System of Special Conditions of Blast Furnace

3.2 Analyses on Optimization and Improvements for Blast Furnace Condition Indicators

The analyses on optimization and improvements for blast furnace condition indicators are done in two steps: The first, by historic data mining, seek the best operation mode which allows the blast furnace to adapt to the current conditions of raw materials and fuels to stabilize the blast furnace conditions; The second, by the deep learning prediction model and the Big Data model, predict an even better operation mode so as to further improve the operating data.

1) Analysis on Adaptability of Blast Furnace Conditions

Provide scientific supports for optimization of the blast furnace conditions in terms of parameter stability and value optimization, etc. by blast furnace condition parameter comparisons & analyses under various preset conditions.

Access quickly the best historic data of the blast furnace conditions by cluster analysis, and compare them to the recent real data of the blast furnace conditions to find the difference, so as to obtain the orientation to the adjustments.

	Good condition	FR<500	FR:500~515	FR>515	Good condition	FR<500	FR:500~515	FR>515
samples	20	282	828	866	fluctuation			
yield	14150	13608	13637	13010	208.42	723.75	574.45	709.9
productivity	2.44	2.35	2.35	2.24	0.04	0.13	0.10	0.12
FR	495.32	493.30	507.63	528.35	6.07	7.74	4.22	11.51
CR	276.91	291.67	294.05	308.53	3.07	18.39	11.62	15.27
SCR	45.03	40.41	44.81	43.89	0.50	8.15	5.44	4.96
PCI	173.37	161.22	168.76	175.93	3.31	18.17	11.72	12.14

Fig. 4 Cluster Analysis on Blast Furnace Condition Indicators

2) Analysis on Matching of Data

Define the rules by which different correlated data match one another, such as the reasonable top adjustment and coordination, reasonable furnace heat control, reasonable raw materials and operation modes, etc. to provide reference for optimization of the blast furnace condition data.

Fig. 5 Control Area Critical Data Mining Module for High Coefficient of Gas Utilization

3.3 Dynamic Management of Blast Furnace Critical DataReference Values

By considering the blast furnace operation in a medium and long term, the reasonable scope of management is defined for the critical data reference values, such as the kinetic energy of blowers under different productions, the relations between hot metal temperature and Si content, the relations between distribution patterns and burden edges, etc. to support standardized operation of blast furnaces.

Fig. 6 Dynamic Optimization of Critical Data for Lower Fuel Ratio

4APPLICATION CASES

The ironmaking Big Data analysis system has been applied to several big blast furnaces in China. It has helped the clients identify the root causes of abnormal blast furnace conditions in the shortest time, take scientific adjustment measures in the correct track to rehabilitate the blast furnaces, recovering from abnormal conditions gradually. Just take an example. One 5,000m^3 blast furnace was noticed to operate in abnormal conditions, once with coefficient of utilization as low as 1.7t/m^{3}d, fuel ratio higher than 600kg/t in the first half year of 2016. The ironmaking Big Data analysis system has been applied to this blast furnace. It was found out the causes of the abnormal conditions by analyzing the historic data of more than 6 years since blow-in. Moreover, it conducted dynamic data analyses, tracked the results of every adjustment every day till mid-Juneof 2016 when its coefficient of utilization was brought back to 2.1t/m^{3}d, fuel ratio to 525kg/t. Throughout the entire process, the data analyses have played a timely and effective role.

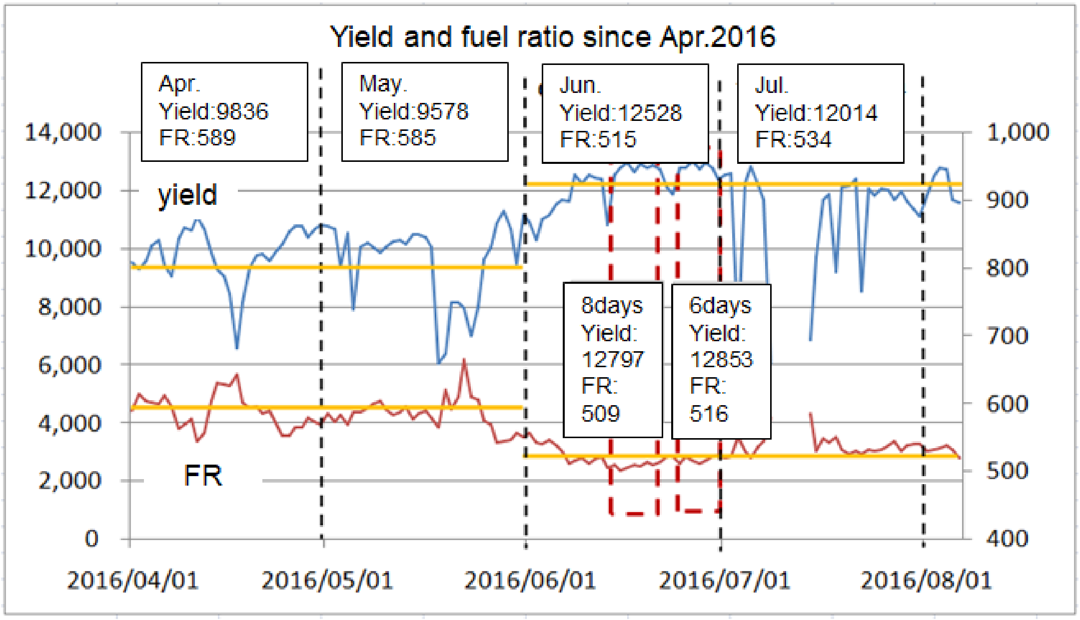

Fig. 7 Variations of Coefficient of Utilization and Fuel Ratio of One 5,000m^3 Blast Furnace in China in 2016

5 CONCLUSIONS

With the development of Big Data, applying Big Data to achieve optimization of blast furnace operation in ironmaking sector has become a technology trend towards intelligent blast furnace ironmaking. The metallurgical engineering companies in China committed to making the process engineering, operation and Big Data fuse have obtained the following technological breakthroughs:

1) Development of the Big Data platform which allows Total Data Management of ironmaking raw materials and fuels, operation and monitoring.

2) Development of the ironmaking Big Data analysis system which takes charge of: Intelligent diagnosis and analysis of blast furnace conditions, analyses on optimization and improvements for blast furnace condition indicators and dynamic management of blast furnace critical data reference values.

3) Real applications in several blast furnaces including a 5,000m^3 one which prove that the blast furnaces have recovered from abnormal conditions, been operating well with higher coefficient of utilization and lower fuel ratio.

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