Statistical Analysis between Output and Energy Consumption of Production Process in Iron and Steel Industry

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ABSTRACT

On the basis of E-P theory of cleaner production, this paper verifies its reliability in terms of prediction of energy consumption using actual production data of output and energy consumption. And then the parameters of the E-P model are determinate by means of least square linear programming method. In addition, we use the actual data to further modify the E-P model in order to improve accuracy of model. It is proved that this model can forecast energy consumption kindly.

Keywords: Production, Energy Consumption

1. Introduction

1.1 Iron and steel industry development in China

The iron and steel industry, which provide fundamental raw material, play a tremendous supporting role to the economic and social development of the country or region.

Current situation of iron and steel industry

Iron and steel industry have made remarkable achievements in China during 60 years’ continuous development and improvement. And it has entered a mature stage of development. With the crude production in China breaking through 100 million metric tons in 1996, the crude production of steel is continuously at the top in the world for a dozen years.

Energy consumption of iron and steel industry

The rapid development of iron and steel industry directly needs large amount of energy. And the energy consumption increased from 182 Mtce (million ton coal equivalent) in 1996 to 597 Mtce in 2012. Therefore, the study on energy saving of iron and steel enterprise has been widely carried out. Meanwhile the energy saving and consumption reducing of iron and steel enterprises in China can be summarized as the following three important stages [1].

(1) China adopted a series of energy saving measures in the 1980s. Such as prevention against “evaporating, emitting, dripping, or leaking”; development and application of monomer technology for improving combustion and improving thermal efficiency; upgrading of process equipment; strengthen management; putting forward the theory and...
concept of system energy saving. But the starting point of energy saving technology is relatively low in this stage.

(2) Advanced commonality-Key Technologies were disseminated and applied in the process of production process in the 90’s of twentieth Century. Such as continuous casting, pulverized coal injection in BF, slag splashing for BOF etc. And these measures realized structure optimization of production process and a large reduction in energy consumption per ton of steel. Meanwhile, these measures reflected the characteristics of in 90’s system energy saving. And manufacture technology backwardly, which include die casting, blooming, open-hearth furnace, mixer and so on, were eliminated. Therefore, the characteristics of energy saving and consumption reduction by eliminating backward production technology in this stage.

(3) The development and application of technology, which included CDQ, Blast furnace gas dry process dust removal, Converter gas dry process dust removal, Residual heat power generation, facilitated the development of energy saving in iron and steel enterprise system. And iron and steel manufacturing to enter the “energy conversion function” period.

1.2 Research methods of energy consumption in iron and steel enterprises

As a large energy consumption industry, iron and steel industry has a strong energy saving potential, because it plays an important role in economic life. So the research on energy consumption of iron and steel enterprises has become the focus of many scholars. At present, the research on energy consumption of iron and steel enterprise is mainly includes two aspects, that is, practical research and model research.

1) Practical research

Practical research refers to a series of effective energy saving measures are summed up by the continuous accumulation of practical production experience and the corresponding theoretical support of technical personnel.

Some energy saving measures, which include increasing the hot charging rate and the hot charging temperature, reducing heating temperature of steel billet under the premise of ensuring the quality of heating and rolling, reasonable design of heating furnace burner, enhancing the recovery of waste heat and energy and improving the capacity of steam supply, adopting energy saving management measures and so on, is put forward for a medium plate plant. So the energy saving effect of this medium plate is improved obviously [2]. Zhang [3] put forward some corresponding energy saving measures, which include strengthening basic management, optimizing ore blending, strengthening operation and technical transformation in sintering process of Masteel NO.1 Iron-making plant. And the energy consumption of this sintering process reached 56.04 kgce/t through these energy saving measures. Si [4] reduce the energy consumption on No. 1 450m BF in Angang Group Yongtong Company by means of strengthening the quality of raw fuel and optimizing the operation system of blast furnace.

These energy saving measures, which are reviewed in the above paragraphs, are constantly summed up from the production and is a more mature experience of energy saving and consumption reduction. And for that, these energy conservation measures are put forward aiming at a specific production process. so these measures are invalid for other production process. Therefore, practical research does not have universal applicability.
2) Model research

Model research refers to that the mathematical model is built by researching production unit mechanism. And corresponding energy saving measures are put forward by looking for the main influencing factors of energy consumption.

LU proposed the concept of standard materials flows diagram of steel manufacturing process. And the influences of materials flows deviated in various ways from standard materials flows diagram on energy intensities of crude steel and of final product were analyzed. YU Qing-bo executed an example calculation of relevant iron and steel enterprises through using the concept of standard materials flows diagram of steel manufacturing process.

Practical research and model research of energy consumption in iron and steel enterprises can greatly promote the reduction of energy consumption of each production unit in iron and steel enterprise. Therefore, this paper establishes the mathematical model between the production and energy consumption after statistical analysis.

2. Statistical analysis of production and energy consumption

2.1 E-P model and its implication

YU collated actual production data using mathematical statistical methods and obtained a linear regression functional relation between the total production unit energy consumption and production quantity, and it was highly correlated with actual production data.

\[ E = E_0 + K \cdot P \]  
\[ e = \frac{E_0}{P + K} \]

In which, \( E \)—total process energy consumption within the statistical cycle, tce; \( E_0 \)—energy consumption not directly related to production within the statistical cycle, such as energy consumed by the company general service, tce; \( P \)—process production within the statistical cycle, t; \( K \)—the normal production state energy intensity, tce/t; \( e \)—the process energy intensity within the statistical cycle, tce/t.

2.2 Principle of parameter determination

The Fig. 1 shows the step how to determine parameter in the E-P energy consumption model.

1) Production research

Production research includes investigation of manufacturing technology and relevant data about material flows and energy flows. The output of unit production process is changing because of the different material flows, energy flows, operation level and production planning. So the production process has the characteristic of fluctuation, and this is mainly manifested in the fluctuation of output and energy consumption.

2) Data preprocessing

The data needs to be preprocessed before mathematical modeling. And abnormal production data should be eliminated. And abnormal production data include wrong record and no record. Wrong record refers to the data that is not in conformity with the actual production due to the mistakes of the records. Such as the production data which
is significantly higher than that of the maximum production capacity of the production unit. And no record refers to the data loss due to various causes.

3) Statistical analysis of output and energy consumption

Statistical analysis of output and energy consumption mainly refers to determine the parameters of the equation (1) by means of least square linear programming method after data preprocessing, and calculate the chance of model winning in the range of error allowed.

3. Case Study

The determination of model parameters is explained through a certain iron and steel company. 365 sets of data on output and energy consumption are obtained in this investigation in 2012. And 280 sets of effective data are obtained after data preprocessing. And equation (3) can be achieved using SPSS software analysis.

\[ E = 12755 + 134.9 \cdot P \]  \hspace{1cm} (3)

It is shown as the black line in Fig. 4. And the fitting degree reached 81.7% between output and energy consumption. So equation (3) can be described as a function of output and energy consumption. Then the \( \pm 5\% \) range of the function to be done (shown as red dashed line in Fig. 2). And the production data are enveloped in the red dashed line of the two groups in Fig. 4. And similar laws are found in other production unit. So the mathematical model between output and energy consumption needs to be modified, that is:

\[ E = 12755 + 134.9 \cdot P + \delta \]  \hspace{1cm} (4)

Which, \( \delta \) is the random number in the range of the fitting function between the production unit and the function on the production unit 5%.

Therefore, linear programming model is build through completing the corresponding statistical analysis on the basis of production unit research. And we can forecast energy consumption through output. It provides a simple and effective method to study the energy consumption of production unit.

4. Conclusions

The paper builds the modified mathematical model through E-P relationship model of cleaner production on the basis of production unit research. And it provides an effective measure to predict the energy consumption of the production unit.
References