INTELLIGENT DECISION MAKING METHOD FOR BDM OF OPERATING PARAMETERSIN BLAST FURNACE IRON-MAKING PROCESS

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Burden distribution at the furnace throat plays an important role in blast furnace (BF) iron-making, which influences the furnace efficiency and stable operation. Burden distribution matrix (BDM) is a key operating variable to adjust a reasonable burden distribution. However, due to complex iron-making mechanism, it is difficult for operators to formulate BDM to achieve a reasonable burden distribution in practice. Focus on this challenge, this paper studies the burden distribution model and proposes a method of adjusting BDM based on intelligent decision making method.

Keywords: blast furnace burden distribution, burden distribution matrix, optimal decision, operation optimization, intelligent optimization algorithm.

Introduction. In a blast furnace (BF), the burden distribution plays a vital role in BF operation, which influences the iron production and the gas flow distribution [1, 2]. Accordingly, the key to keep a smooth operation environment is to formulate a proper burden distribution matrix (BDM).Yong Zhang [3] proposed an output shape model of the multi-ring distribution to establish the relationship between BDM and the output shape of the burden, and the burden charging process is shown as Fig. 1. BDM consists of two parts, where α represents the chute angle, c represents the rotation circle, so the parameter of BDM are asfollows:

$$\begin{cases} \alpha = [\alpha_1, \ldots, \alpha_m] \in \mathrm{R}^{m\times 1}, \alpha_i \in [\alpha_{\min}, \alpha_{\max}]; \\ c = [c_1, \ldots, c_m]^T \in \mathrm{N}^{m\times 1}; \\ \boldsymbol{u} = [\alpha, c]. \end{cases} \tag{1}$$

The distribution of the burden in the furnace throat affects the stable operation of the blast furnace. The early blast furnace process gives a model of "platform plus funnel" for the distribution of the charge surface pattern in the furnace throat, and experience shows that when the distribution of the charge surface in the furnace throat is as shown in Fig. 2, the gas utilization rate is high and the airflow distribution is stable.

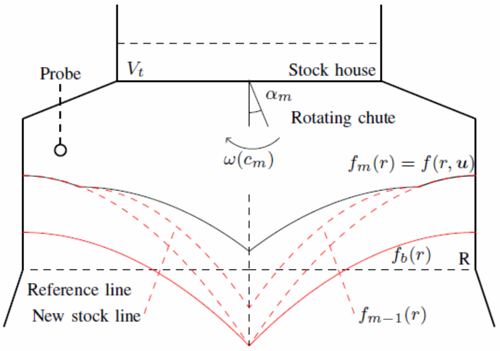

Fig. 1. The process of burden charging

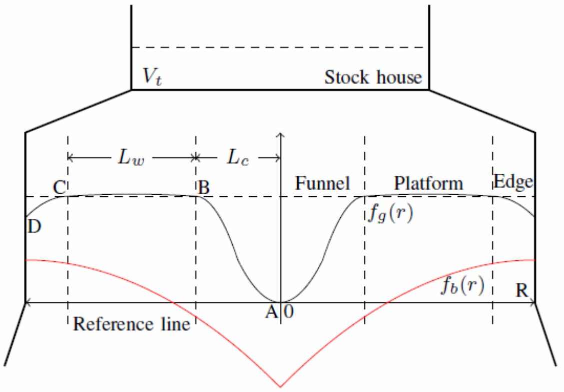

Fig. 2. The optimal shape of burden surface

Recently,Yixin Yin's team of University of Science and Technology Beijing has made full use of blast furnace production data and blast furnace radar surface inspection technology to construct a multi-objective surface distribution optimization model with gas utilization rate, ore-coke ratio and other production indexes as the optimization targets, and has given a 'curve-linear-curve' three-stage method to describe the optimal surface distribution of blast furnace operation [4]. As shown in Fig. 2, section AB is regarded as the funnel area, section BC is the platform area, and section CD is the edge area, so the mathematical model can be expressed as follows:

$$fg_{(r)}=\begin{cases}-0.75\cos(0{,}5\pi r)+1.30420\le r\le 2.0;\\ \qquad\qquad\qquad 2.054220\le r\le 3.4;\\ 2.0542-0.35(r-3.45)^2 3.4\le r\le 4.5.\end{cases} \tag{2}$$

By using the above models, we give the formulation of this paper as follows:

$$\min J(\boldsymbol{u})\,|\,\alpha_j=\int_0^R (f(r,\boldsymbol{u}_j)-f_g(r))^2\,dr, \tag{3}$$

s.t.

$$\begin{cases}V_t=\int_0^R 2\pi R(f(r,\alpha\,|\,c)-f_b(r))dr;\\ \alpha_{\min}\le\alpha_1<\ldots<\alpha_m\le\alpha_{\max}.\end{cases} \tag{4}$$

Where $\alpha_{\max}$ and $\alpha_{\min}$ are the lower and upper bounds of α_i. The objective function (3) is to minimise the deviation between the system. output shape and the optimal shape of BF. Constraints (4) defines the value ranges for the chute angleand ensures that material layer thickness distribution meets the volume constraint of the process.

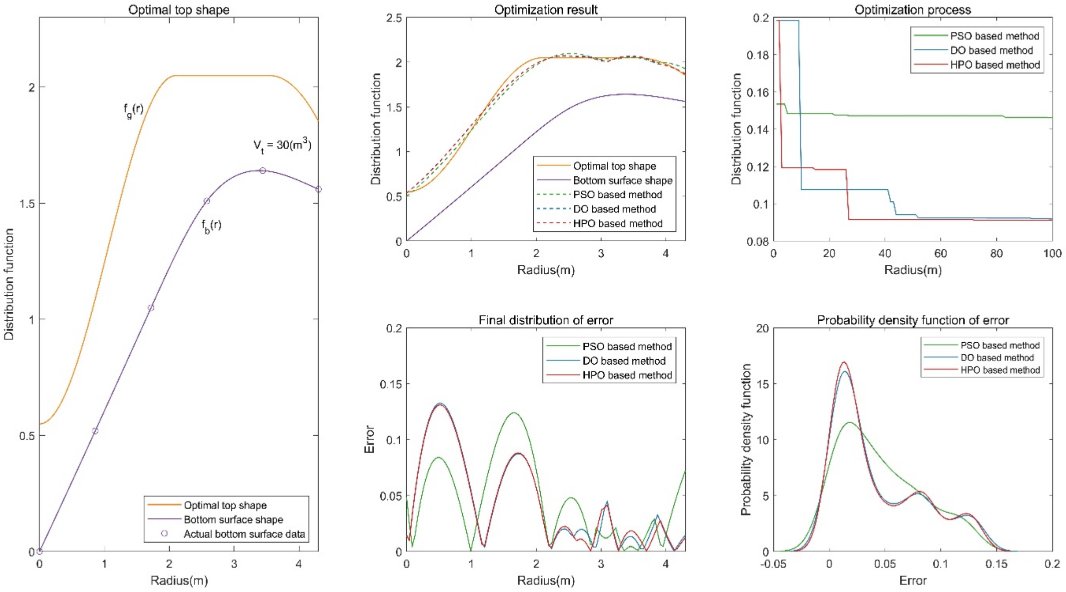

Fig. 3. The simulation results

Optimized BDM under expected burden surface $f_g(r)$

Algorithm	α_1/c_1	α_1/c_1	α_1/c_1	α_1/c_1	α_1/c_1	J/t_{Matlab}
PSO	42.1085 / 3	37.773 / 2	34.1689 / 2	29.9154 / 2	29.2143 / 1	0.1464 / 1.83*s*
DO	41.1411 / 3	37.6929 / 2	32.0794 / 2	30.6988 / 2	28.2573 / 1	0.0918 / 0.16*s*
HPO	41.1039 / 3	37.8264 / 2	33.5282 / 2	30.5486 / 2	28.3043 / 1	0.0910 / 2.07*s*

Experimental method. Intelligent optimization algorithm provides an effective way to solve optimization problems of finite variables. In this paper, Particle Swarm Optimization (PSO), Dandelion Optimizer (DO) and Hunter-prey Optimization (HPO) are used as main algorithms for the model from the burden surface to BDM. In order to testify the effectiveness and rationality of the decision model, this paper adapts the parameter data of the real BF to testify. The throat radius r of BF is 4.3, the burden volume V_t is 30, the rotation circle c is represented as $[3 \quad 2 \quad 2 \quad 2 \quad 1]^T$.

Comparison results of decision model based on different algorithms are given in Fig. 3 and table. All of them can optimization results are close to the optimal shape of BF. It is necessary to compare the algorithm with other indicatorsIt can be seen that the curve has a significant decline in both early and late iterations based on DO and HPO, and it can finally obtain higher convergence accuracy than PSO. The error of the optimization results are all within the acceptable range, meanwhile the probability density functions of the error are all converging to zero.We can see from table that DO has the shortest optimization time and HPO is able to obtain a minimum value.

Conclusion. Burden distribution is one of the most important controlling factors to the conditions of the BF and reasonable parameters of BDM can realize the optimal burden surface. This study proposes a decision method to determine the suitable BDM based on intelligent decision making method.

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DESIGN OF MINIATURIZED EXTERNAL DUAL-BAND MICROSTRIP CIRCULAR PATCH ANTENNA FOR MICROWAVE HYPERTHERMIA

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This paper designs a miniaturized in vitro dual-band microstrip circular patch antenna for microwave thermal therapy, with antenna resonant frequencies of 915 MHz and 2450 MHz and a circular patch size of 7 mm radius. It is capable of achieving a reflection coefficient of –25.51 dB at 915 MHz with a bandwidth of 30 MHz (S11 < –10dB) and –36.84 dB at 2450 MHz with a bandwidth of 270 MHz (S11 < –10 dB). The antenna can form an energy focusing area in the human surface tissue below the circular patch, and the focal point position is the same at both frequencies. After simulation, it is verified that 915 MHz can achieve a larger radiation area than 2450 MH with the same SAR field penetration depth. It is possible to select the appropriate frequency for the size of superficial tumor to achieve the effect of precise tumor treatment.

Keywords: microwave hyperthermia; non-invasive ; miniaturization ; dual band ; microstrip circular patch antenna

Introduction. Microwave hyperthermia for tumor, is the use of high-frequency electromagnetic waves in human tissue to produce thermal effects, the temperature of tissue cells to 41.5 °C above the effective treatment temperature, and maintain a period of time, thereby accelerating cancer cell death, while minimizing the damage to normal cells. At present, there are two main types of microwave hyperthermia antennas: invasive and non-invasive. The invasive antenna is directly inserted into the tumor area for heating treatment [1]. Non-invasive antennas use a single antenna or array antenna to gather energy to the tumor site and heat the tumor tissue to achieve the purpose of treatment [2]. Compared with invasive hyperthermia, non-invasive in vitro hyperthermia can not only reduce the damage to the human body during treatment, but also safely and effectively inhibit the development of tumors [2].

Microwave hyperthermia antenna usually uses ISM (industrial, scientific and medical) band of 434 MHz, 915 MHz and 2450 MHz three frequencies [3]. Single antenna form of hyperthermia antenna usually uses patch antenna [2–4], waveguide antenna [5], etc. Most of the existing microwave hyperthermia antennas work at a resonant frequency and can only ablate fixed-size tumors [6]. Because the frequency of electromagnetic wave is inversely proportional to the wavelength, the radiation area of electromagnetic wave is