

Research on the optimization algorithm of sintering ingredients

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Abstract: This paper analyzes the current research status of steel sintering ingredients at home and abroad, and compares the optimization algorithms used in sintering ingredients. The linear programming method has been relatively mature, easy to operate; But to solve the complex and nonlinear large-scale problem, the genetic algorithm, particle swarm algorithm are more efficient. The sintering burden process is an important part of the sintering process, and the optimization algorithm is the key link in the process of sintering burden studies. In the future research, the advantages of each optimization algorithm can be combined to solve the problem of ingredients better.

1. Introduction

Significant achievements have been made in the long-term studies of sintering ingredients at home and abroad ^[1]. But due to less domestic iron ore resources in China, most of the current domestic steel enterprises basically rely on imported iron ore, iron ore source of instability, for the influences of the sintering burden ^[2]. Therefore, the research development of domestic sintering burden is on the premise of guarantee metallurgical efficiency decline, through the establishment of the optimization model, optimization algorithm to solve the optimization ratio to reduce costs and reduce the purpose of the pollutants. Overseas iron ore resources are abundant, which pay less attention of cost to the level of research, mainly studies the different ratio of raw materials to produce agglomerate structure and the relationship between the metallurgical properties, so the ratio of raw materials basically stable, the sintering of sulfur content in the form of lower ^[3-4].

The sintering process is mainly divided into four processes: ingredients, mixed granule, segregation fabric and sintering block^[5]. The sintering ingredient is the first step in the process of sintering ^[6]. Each raw material proportioning of the process of ingredients is directly influences the quality of sinter, therefore the sintering burden has been an important research topic in iron and steel production process, intelligent optimization algorithm is the core of the sintering burden the research process and hot ^[7]. At present, there are few researches on the application characteristics and comparative analysis of intelligent optimization algorithm in steel sintering ingredients. Therefore, this paper analyzes and contrasts the optimization algorithm used in steel sintering.

2. Optimization algorithm of sintering ingredients

Generally speaking, the purpose of the sintering batching problem model is to reduce the cost as much as possible. In order to ensure the properties of sinter and metallurgical properties meet the actual production process requirements. Although the mathematical models of each optimization algorithm are similar, they still have their own characteristics and calculation conditions. This chapter introduces the characteristics of the optimization algorithm and the current research situation.

2.1. Linear programming



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The linear programming method is the first optimization algorithm applied to the sintering ingredients, and the sintering ingredients can be converted into linear programming problems. However, through the establishment of mathematical model, the optimal solution of sintering ingredients is solved. The establishment of mathematical model of linear programming includes objective function and constraint condition. In the sintering ingredients, the target function is usually the lowest cost, and the requirements of the quality index and pollutant discharge are the constraint conditions and the solution of the problem is solved. The quality indexes generally include TFe, CaO, SiO₂, MgO, Al₂O₃, etc. Suppose there are n raw materials, the ratio of each raw material is X_i ($i=1,2,3,\dots$). The unit price of each raw material is P_i ($i=1,2,3,\dots$). In order to ensure that all raw materials have a combined ratio of 1, the objective function is expressed as:

$$\text{Min} \sum_{i=1}^n X_i \cdot P_i \quad (1)$$

$$\sum_{i=1}^n X_i = 1 \quad (2)$$

$$b_{j\min} \leq \sum_{i=1}^n w_{ij} \cdot x_i \leq b_{j\max} \quad (3)$$

According to the requirement of the sintering process of sintering ore and the ratio of each raw material requirements, the general constraint condition as shown in (3), the W_{ij} is a raw material of TFe, CaO, SiO₂, MgO, Al₂O₃. $b_{j\min}$ with $b_{j\max}$ respectively each quality index of the upper limit and lower limit.

The earliest application of linear programming to solve a burdening optimization problem is in the 1980 s, Zhou Jingsheng^[8] using the linear programming method to solve the best proportioning, compared with the actual production reduced 3.95 yuan per ton, sintering process indicators are also improved. With the increasing of the constraint conditions of sintering ingredients, the problem of sintering ingredients is more nonlinear. Wang Wei and Chen Daolin^[6] introduced the relaxation variable on this basis and put it into actual production to save 5.71 yuan per ton of sinter. Linear programming has been developed for decades, the technology is relatively mature. At the same time, it is of great significance to the current situation of inadequate iron ore supply and environmental protection in China.

2.2. Genetic algorithm

Genetic algorithm is an adaptive global optimization search algorithm for simulating the genetic evolution of organisms in nature. The genetic algorithm was first proposed by professor Holland of the United States^[9], which drew on Mendel's theory of genetics and evolution of Darwinian "survival of the fittest". The essence of genetic algorithm is a kind of parallel global search method, which automatically acquires the content of search space in the search process and controls the search direction automatically, thus obtaining the optimal solution. The mathematical model equation of genetic algorithm is similar to the mathematical model equation of linear programming. But the different is, the penalty function in the genetic algorithm can flexibly handle various constraints, by adjusting the weights of penalty function to control the priority level of each constraint condition, make a burdening optimization model for solving process is more conform to the requirements of the iron and steel production. The flow chart of genetic algorithm is shown in figure 1.

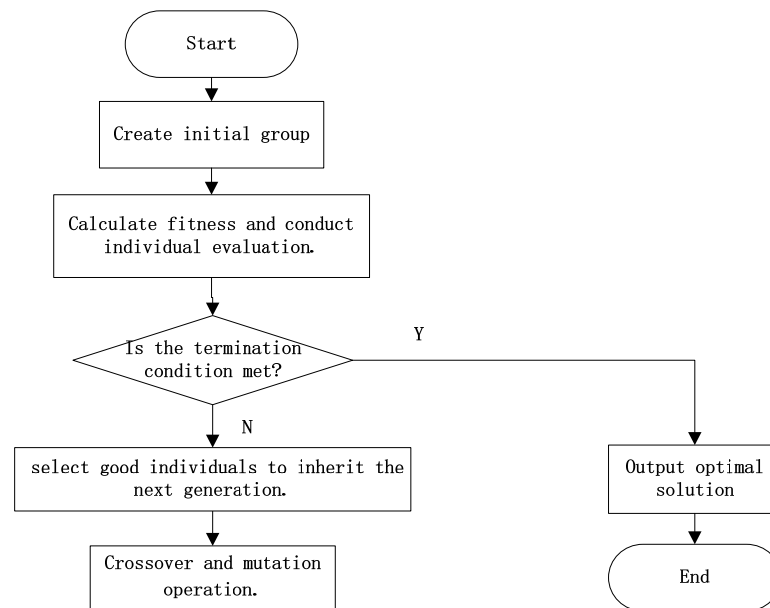


Fig. 1. flow chart of genetic algorithm

In terms of sintering ingredients, with the increasing of variable and constraint conditions and the increase of model complexity. Because the genetic algorithm can effectively solve the problem of nonlinear and multi-objective optimization, it is widely used in the sintering ingredients. Hou Wumin^[10] used the genetic algorithm to the sintering burden, under the premise of meeting the actual production requirement, optimizing the ingredients make the cost of raw material was reduced by 6.471 yuan per ton, TFe content increased 0.2 at the same time. Li Zhi, Yao Zhubin, etc.^[11] combining immune algorithm with genetic algorithm, applied to the ingredients in the process, through the simulation test shows that meet the requirement of practical production, and reduce the cost by about 10.32%, while improving the comprehensive utilization of various kinds of clinker.

2.3. Particle swarm optimization

Particle swarm optimization^[12] is derived from the regularity of bird population activity. It simulates the foraging behavior of birds, compares the solving space to the flight space in which birds hunt for food, and compares each bird to a particle regardless of its mass and volume. Each particle represents a possible solution to the problem. The process of finding the optimal solution is regarded as the foraging process of the birds, and then the complex optimization problem is solved. The particle swarm algorithm is similar to other evolutionary algorithms, which can solve complex problem optimization search through the collaboration and competition among individuals. But the particle swarm optimization (pso) algorithm with other evolutionary algorithms are different, each particle moves in a certain speed in the solution space, and constantly to p_{best} optimal solution to its own history and community history gathered g_{best} optimal solution.

Suppose that in the target search space of a D dimension, there are N particles that form a community, where i is represented as a vector of D dimension $X_i=(x_{i1},x_{i2},x_{i3},...), (i=1,2,3...n)$. The velocity of each particle is recorded as $V_i=(v_{i1},v_{i2},v_{i3},...)$; The optimal solution is $P_{best}=(p_{i1},p_{i2},p_{i3},...)$; The optimal solution of the whole particle swarm is the global optimal solution $g_{best}=(g_1,g_2,g_3,...g_D)$. In finding the optimal solution of the individual optimal and global optimal, the particle is updated according to the following two equations:

$$v_{ij}(t+1) = w \bullet v_{ij}(t) + c_1 r_1 [p_{ij}(t) - x_{ij}(t)] + c_2 r_2 [p_{gj}(t) - x_{ij}(t)] \quad (4)$$

$$x_{ij}(t+1) = x_{ij}(t) + v_{ij}(t+1) \quad (5)$$

W is the inertia weight; c_1 and c_2 are learning factors, which are also called accelerators. r_1 and r_2 are random numbers uniformly distributed in the range of $[0,1]$. The flow chart of particle swarm algorithm is shown in figure 2.

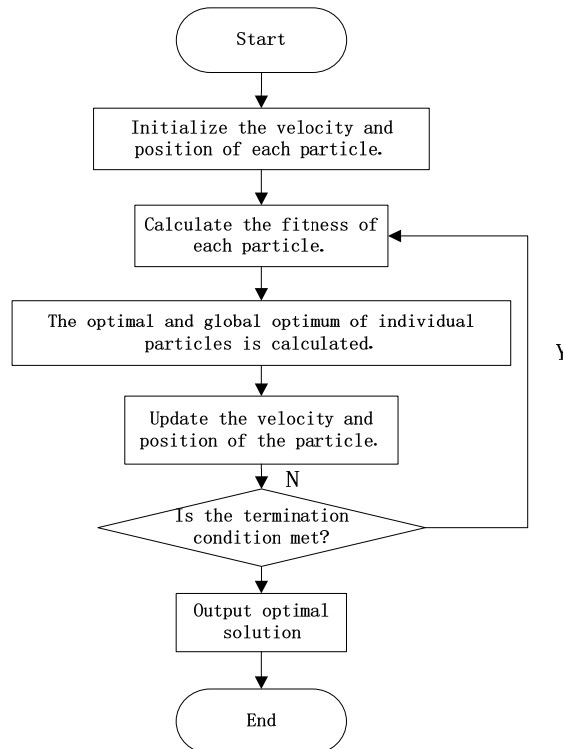


Fig. 2. flow diagram of particle swarm algorithm.

Wu Min et al. ^[13] introduced conjugate gradient method into the standard particle swarm optimization algorithm, and adjusted the objective function properly when the population information stagnated. The optimization results were compared with the standard particle swarm optimization algorithm. The harmful elements are restricted more effectively and the content of TFe is also increased. At the same time, the cost per ton is reduced by 8.2 yuan, calculated by 1 million tons per year, which can save 8.21 million yuan per year, thus saving a large amount of money for the enterprise. Particle swarm optimization (PSO) algorithm has no high requirement for the mathematical model of the optimization problem and avoids the complexity of the ordinary mathematical method. Therefore, it is not necessary for the user to have too high knowledge of mathematical theory and is suitable for engineering personnel.

3. Analysis and comparison of optimization algorithm

Because each optimization algorithm has different design ideas, the optimization algorithm has its own advantages and disadvantages. In table 1, the advantages and disadvantages and calculation conditions of each optimization algorithm are summarized.

Table 1. Comparison analysis table of optimization algorithm

	Advantages	Disadvantages	Calculation conditions
Linear programming	Simple and easy to operate	maybe no solution to the complexity problem	Small scale

Genetic algorithm	It's a parallel adaptive probability search technology	It has the "premature" phenomenon	multi-objective optimization problem
Particle-swarm optimization	It is easy to understand, and the convergence rate is fast	Parameter setting is more difficult; It tends to stagnate	Optimization problems

Among them, the linear programming is the first optimization algorithm used in the sintering process, and the linear programming method has gradually matured in the course of several decades. However, with the increasing complexity of the problem solving, the linear programming method has become less and less efficient, and even can not be solved. Genetic algorithm and particle swarm algorithm are all intelligent algorithms. However, all of the two algorithms have their own shortcomings, and the algorithm needs to be improved and integrated in order to get a better optimal solution. This is also the main direction of current optimization problem research.

4. Conclusion

Through the comparison and analysis of each optimization algorithm, we can see that the optimization algorithm has its own characteristics. In the case of reducing cost and meeting the requirements of actual production process, the following points should be considered for the sintering ingredients:

- Using the advantages of the integrated optimization algorithm to improve the operation efficiency and solve the quality, this is the direction of the improvement of the algorithm in the future.
- The restriction of harmful substances and air pollution gases, Reduce the production of harmful substances and air pollutants.

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