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Journal of Building Material Science
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ARTICLE

Optimization Model and Pollution Treatment of Sintering Ore Distribution

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ARTICLE INFO

Article history
Received: 30 November 2020
Accepted: 10 January 2021
Published Online: 31 January 2021

Keywords:
Sinter blending
Optimized blending
TOPSIS
Desulfurization and emission reduction

ABSTRACT

Sintering process plays an important role in iron and steel smelting process. The subsequent production of blast furnace ironmaking is directly affected by the quality of sinter. Among them, the proportion of raw materials and the advanced degree of sintering process are the two main factors affecting the quality of sinter. Because the control parameters of sintering process are too many and the physical and chemical process is too complex, it is difficult to establish and control the model accurately. Therefore, workers have long relied on experience to set temperature and other factors to engage in production, resulting in the quality of sinter is unstable, the cost is not easy to be controlled. Moreover, the flue gas produced in the sintering process will have different effects on the environment. Through the data analysis of the ore distribution scheme and the results of the physicochemical analysis of sinter in a steel plant, two aspects of the work are completed: one is to establish the optimal model of the cost of the sintering process, and the most suitable temperature for the sintering process. The second is the analysis of harmful components produced in sintering process.

1. Introduction

Because sintering can greatly improve the quality and value of ore, the process of steel production in domestic steel mills is mostly carried out by sintering process. Through sintering process, the scarce components in natural ore are enriched, and the ore is transformed into artificial rich ore with higher quality and value, so as to meet the demand for rich ore resources in industrial production. Therefore, sintering process re-industrial production occupies an indispensable position. If the sintering process can be optimized, and the optimum ambient temperature of sintering process can be predicted. The cost of sintering process can be significantly reduced, and the quality of sinter can be significantly improved to provide more high quality materials for industrial production. At the same time, due to the rich sulfur element in the mineral raw materials of the sintering process, the release of sulfur element will produce a large amount of pollutants to the environment during the sintering process. According to the statistics of relevant departments, the sintering process is SO in production$_2$Emissions account for about 80 per cent of total steel production[1]. If desulphurization is achieved in the sintering process, the pollution discharge

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DOI: https://doi.org/10.30564/jbms.v2i1.2718

of the sintering process and the quality of the sinter will be improved considerably. In this paper, the optimal ore blending model of sintering process and the treatment of subsequent flue gas pollutants are realized by optimizing the algorithm and the treatment of polluting compounds such as sulfur-containing elements.

2. Sintering Process

2.1 Sintering Process

Sintering is an important link in metallurgical process. If we want to improve sintering process, optimize sintering blending and establish optimal temperature prediction model, we must have a certain degree of understanding of sintering process. Figure 1 is a typical sintering process flow chart.

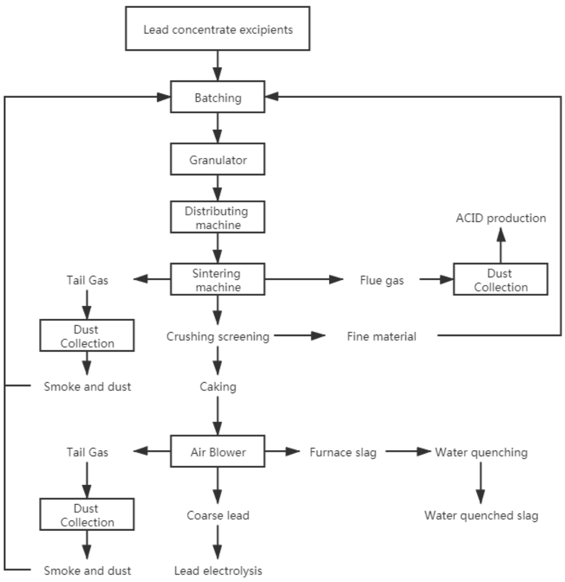


Figure 1. Typical sintering process

According to the flow chart of the sintering process, the main energy consumption types in the sintering process are electric energy, water energy, gas and solid fuel. In the process of sintering, the main place of these energy sources is to provide suitable temperature for sintering process, so that all kinds of elemental compounds in mineral raw materials can be successfully reacted and enriched. At the same time, in each process of sintering process, a large amount of tail gas, smoke and dust produced and the treatment of these pollutants are all necessary processes for sintering process to realize the quality of sinter. Therefore, in order to improve the quality of sinter and reduce the environmental pollution of sintering process, the temperature prediction is chosen as the core to achieve the established goal of reducing sintering cost and the removal of nitrogen and sulfur compounds.

2.2 Analysis of Raw Material Composition of Sinter

2.2.1 Design Experiments

Because of the limitation of the condition, the practical experiment can not be carried out in this paper, so the sintering material used in the field sintering of a steel plant is chosen as the main body of the analysis.

Table 1. Chemical composition of field sinter (mass fraction) [2]

Name of name	TFe	FeO	CaO	SiO_2	MgO	Al_2O_3	TiO_2
Chiron A	64.75	0.14	0.00	2.35	0.24	1.60	0.150
Chiron B	62.70	0.29	0.07	4.15	0.21	2.16	0.120
Chiron C	57.53	0.40	0.68	6.42	0.59	3.11	0.300
Chiron D	61.59	0.27	0.46	5.55	0.55	1.18	0.260
magnetite A	65.51	19.41	0.24	6.07	0.61	0.44	0.150
magnetite B	66.33	23.52	0.29	5.55	0.72	0.39	0.081
magnetite C	63.92	27.92	1.49	1.16	3.53	0.61	2.480

Table 2. Design of experimental scheme for ore blending

Programme series	Mineral types	Minimum ratio
No .1	Chiron A	10
No .2	Chiron B	10
3 No. No	magnetite A	5

Table 3. Theoretical Chemical Composition and Basic Characteristics of Sintering of Mixed Minerals [3]

	Characteristics of sintering foundation				
	Mineral powder ratio	Assimilation temperature	Liquid phase liquidity	Strength of bonding phase	Continuous crystal strength
No .1	10	1257.0	0.291	1412.772	523.735
	15	1258.3	0.237	1450.885	614.782
	21.12	1260.7	0.211	1552.233	745.789
	25	1262.3	0.188	1580.035	920.213
	30	1266.7	0.211	1626.549	974.041
No .2	10	1259.0	0.283	1256.663	545.628
	15	1261.0	0.237	1295.431	580.020
	20	1262.0	0.182	1483.557	619.230
	25	1262.0	0.173	1417.383	718.792
	30	1261.3	0.134	1386.552	936.525
	35	1260.3	0.054	1306.269	1116.883
No .3	5	1259.7	0.138	2329.156	1080.717
	10	1264.7	0.107	1807.847	801.607
	13.3	1260.7	0.211	1700.381	745.789
	20	1264.0	0.615	1655.137	770.241
	25	1269.3	0.907	1302.965	759.943
	30	1270.7	1.241	1257.197	729.652

 DOI: https://doi.org/10.30564/jbms.v2i1.2718

From the data in Table 1, we can see the composition and content of various elemental compounds in different kinds of ores. Based on this, three groups of sintering cup experiments were designed, and the properties of sintered mineral products were compared with those of different blending ratios. Table 3 shows the experimental data of three ore blending methods under different ore powder ratios.

2.2.2 Topsis Treatment of Priority Properties and Scores of Sintering Products in Each Group

After the data in Table 3 are obtained from the experiment, the Topsis algorithm is used to compare the quality of sinter obtained in 17 groups of experiments. Considering the cost of sintering process and the quality of sinter. The assimilation temperature of the sintered ore is taken as a great type to improve its metal properties, the liquid phase fluidity is taken as a minimum type, so that the difficulty of removing the unrelated impurity elements in the sintering process can be reduced to reduce the cost, and the bonding phase strength and the continuous crystal strength are set as very small and maximum, respectively. Implementation using Matlab code:

Forward formula: $M=\max\{|x_i - x_{best}|\}$, $x_{Average}=1-(|xi-xbest|)/M$.

(1) Bring the two columns of data in Table 2 into the forward formula, and get the corresponding M value of each data;

(2) To add tables to the work area X, import the sinter data from 17 groups of experiments in Table 3 into X; table

(3) Import Topsis code:

(4) The code can realize the calculation of the priority of 17 groups of data. The results are as follows:

Normalized Matrix			
0.241509555	0.237275251	0.261364074	0.159866718
0.241759327	0.250762476	0.250493774	0.187658225
0.242220443	0.257256325	0.221588068	0.227647264
0.242527853	0.263000884	0.213658593	0.280889061
0.243373233	0.257256325	0.200392224	0.297319709
0.241893819	0.239273358	0.305888295	0.166549414
0.242278082	0.250762476	0.294831181	0.17704735
0.242470214	0.264499464	0.241175314	0.189015948
0.242470214	0.266747335	0.260048959	0.219406604
0.242335722	0.276488108	0.268842343	0.285868193
0.24214359	0.296469182	0.291740049	0.340921305
0.242028311	0.275489055	0	0.329881867
0.242988969	0.283231721	0.148683787	0.244685347
0.242220443	0.257256325	0.179334423	0.227647264
0.242854477	0.156351902	0.192238572	0.235111078
0.243872775	0.083420983	0.292682391	0.231967681
0.24414176	0	0.305735992	0.222721549

Figure 2.

Table 4

Prioritization of experimental data									
Group	17	16	15	12	5	11	4	1	14
	6	10	3	13	2	7	9	8	

2.2.3 Analytic Hierarchy Process Addressing the Weight of Each Nature

From the experimental data in figure 3, the priority of each experimental data can be more accurate to judge the four attributes of sinter, which occupy an important layer in the overall basic performance of sinter. The weight of the four basic attributes in the overall metallurgical performance can be calculated respectively:

(1) Constructing Relational Matrix:

	Assimilation temperature	Liquid phase liquidity	Strength of bonding phase	Continuous crystal strength
Assimilation temperature	1	3	5	4
Liquid phase liquidity	1/3	1	2	1.50
Strength of bonding phase	0.2	0.5	1	0.80
Continuous crystal strength	0.25	0.75	1.25	1

(2) use the Matlab function to solve the corresponding weights of four attributes:

Four attributes are 3. weighted:

By the above code, the CR value of the relation matrix is less than 0.10, so the weight result is consistent, and the relation matrix does not need to be modified. and the overall weights of the four attributes obtained are :0.5553,0.1997,0.1062,0.1388.

2.2.4 Fitting and Predicting Optimal Model for Sinter Blending

It can be inferred from the above process that the assimilation temperature and liquid phase fluidity account for the larger weight in the basic attributes of sintering condition, so the optimum ratio of raw materials in sinter blending is inferred based on the two attributes.

(1) A of hematite

The two groups of data with the highest weight in Table 2 were fitted with the independent variable of the proportion of powder distribution

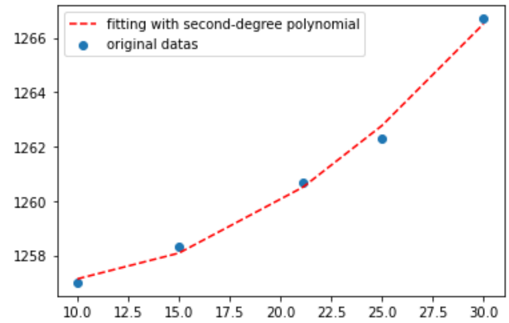
Assimilation temperature:

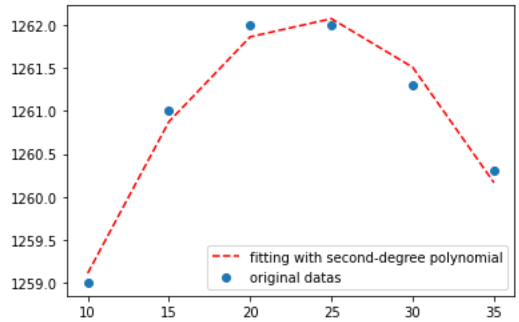
And the expression of the corresponding fitting function is x :0.01859^2 0.2747 x +1258

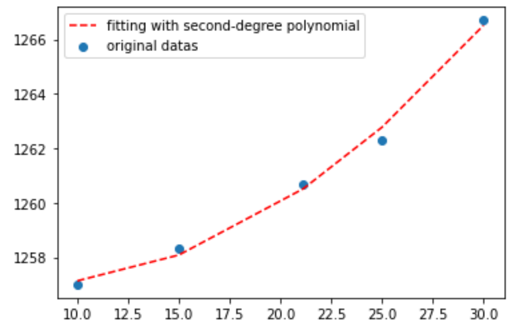
By the same token, the liquid phase fluidity function is x :0.0004263^2 0.02119 x +0.4605

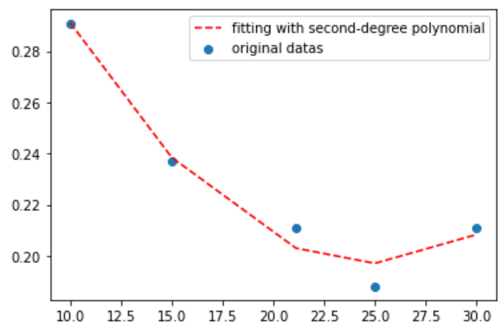
And the corresponding images are:

 DOI: https://doi.org/10.30564/jbms.v2i1.2718









It can be obtained from the analysis of the diagram that when the ratio of powder distribution is 15-25, the assimilation temperature of sinter is higher and the liquid phase fluidity of sintered products is low, that is, the quality of sintered mineral products is relatively high and the energy consumption cost of sintering process is relatively low.

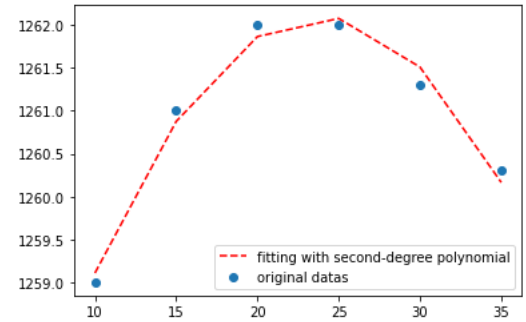
(2) A of hematite B, magnetite

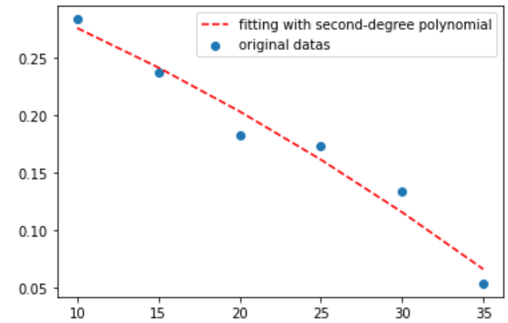
According to the fitting process of the two attributes of the above hematite A, the fitting process can be obtained:

Assimilation temperature :$-0.01557\ x^2 +0.743\ x +1253$

Liquid fluidity :$-7.571*10^{-5}\ x^2 -0.004953\ x +0.3325$

And the corresponding images of the two groups of fitting functions are as follows:



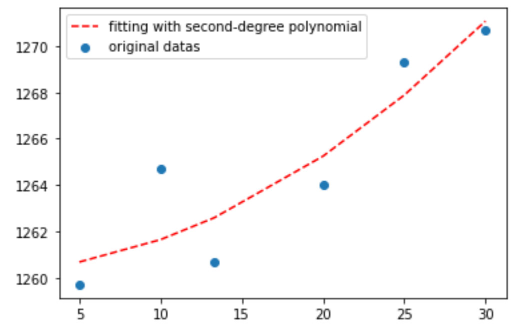


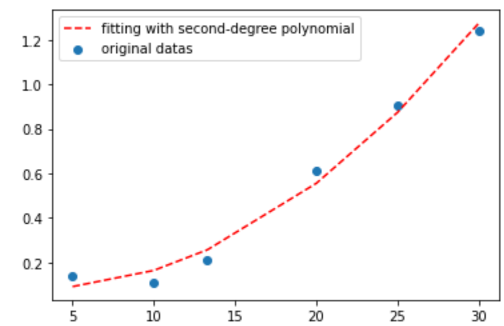
A fitting function corresponding to two sets of data in magnetite A is:

Assimilation temperature: $x\ 0.01114^2 +0.02623\ x +1260$

Liquid fluidity: $x\ 0.001642^2\ 0.01009\ x +0.101$

The corresponding image of the fitting function is:





The fitting curve shows that the metal properties A hematite B and magnet ore have higher assimilation temperature and lower liquid phase fluidity when the powder ratio is 20-27% and 9-13%, respectively.

3. Flue Gas Treatment

Because the raw materials of sintering process contain a large number of sulfur compounds, most of the pollution in sintering process is flue gas pollution, among which harmful gas pollutants mainly include SO2, NOX and so on.

3.1 Sulfur Compounds in Flue Gas

3.1.1 Produce

SO of sulfur compounds in flue gas_2During the sintering process, the main way is the oxidation reaction of sulfide (FeS2,FeS) in iron powder [4]:

$$2FeS_2\ O +11/2_2 =Fe_2O_3 +4\ SO_2 \quad (1)$$

$$2FeS_2 =2\ FeS +2\ S \quad (2)$$

$$S+O_2 =SO_2 \quad (3)$$

$$2FeS +7/2FeS +O_2 =Fe_2O_3\ SO +2_2 \quad (4)$$

However, most of the sulfates in iron powder release gaseous sulfide by decomposition reaction during sintering [5]. Organic sulfur in solid fuels is oxidized to form gaseous sulfides.

3.1.2 Handling

(1) Emission reductions at source:

The main pollution elements in sintering flue gas are mostly from sintering raw materials, so the content of gaseous pollutants in flue gas can be greatly reduced by controlling the composition of sintering raw materials, such as reducing the ratio of coke powder and quicklime, adjusting the ratio of sintered iron materials, or reasonably controlling the moisture content of mixture, so as to achieve the emission reduction at the source [6]. Long Hongming et al [7] SO based on sintering $process_2$ A new method for desulphurization by adding urea solid particles evenly in the fault layer of sintered material is proposed. An industrial test shows that the ratio of urea to SO is 0.09% in the super-wet layer $mixture_2$The emission reduction has great effect. Su Yudong [8]. By increasing the water content of the mixture, increasing the height of the sintered material layer and the basicity of quicklime, and reducing the ratio of coke powder and anthracite in the mixture, the NO emission concentration can be reduced by about 20% under the premise of ensuring the quality of sinter.

(2) Absorption degradation

For now, SO_2The treatment technology has been very perfect, including dry, wet and semi-dry desulfurization process. Among them, lime-gypsum wet desulfurization process is the most widely used, the best effect, the most mature technology desulfurization method. Its actual process is as follows:

Limestone (CaCO) is generally used in the lime-gypsum $process_3$) or lime (CaO) as a desulfurization absorbent, crushing and grinding limestone into powdered and mixed water to form an absorbent slurry, which is fed into a desulfurization absorber. At the absorption tower, the absorbent slurry is mixed with the flue gas, and the SO in the flue gas_2By CaCO with $slurry_3$and oxygen pumped into the air for chemical reactions to form gypsum (CaSO); and_4The slurry is removed [9]. The gypsum slurry formed is treated by a vacuum belt dehydrator to obtain gypsum [10].

Main chemical reaction formula of lime-gypsum desulphurization process [11]. As follows:

$$CaO+H_2O \rightarrow Ca\ (O\ H)_2 \quad (5)$$

$$Ca\ (OH)_2+SO_2H +1/2_2O \rightarrow CaSO_3::1/2\ H_2O+H_2O \quad (6)$$

$$Ca\ (OH)_2+SO_3+H_2O \rightarrow CaSO_4H\ 2_2O \quad (7)$$

$$CaSO_3::1/2\ H_2O\ O+1/2_2H +3/2_2O \rightarrow CaSO_4H\ 2_2O \quad (8)$$

4. Conclusions

4.1 Conclusion

(1) in the basic properties of sintered mineral products, the higher weight is its assimilation temperature and liquid phase fluidity.

(2) from the above fitting images, the metallurgical properties of the sintered products are superior when the proportion of powder A hematite is 15-25. The ratio of powder distribution of hematite B and magnetite A can be reduced to 20-27% and 9-13% respectively, thus further improving the metallurgical properties of sintering products and reducing the energy consumption cost of sintering process.

4.2 Comprehensive Consideration and Prospect of Desulfurization Process in Sintering Process

(1) Gaseous pollutants in sintered flue gas mainly include SO_2NOx and dioxins[12]. As China sinter environmental protection standards are gradually improved, the SO is_2NOx and dioxin emissions are severely restricted. Current SO in flue gas_2The removal technology is mature,

DOI: https://doi.org/10.30564/jbms.v2i1.2718

including dry, wet and semi-dry. Compared with wet desulfurization process, semi-dry desulfurization process has no acid substance and no waste water discharge, which is more in line with environmental protection requirements. The more mature technology NOx flue gas is SCR denitrification process [13]. The rational reuse of desulphurization gypsum will be the focus of future research on sintering flue gas desulfurization technology.

(2) Consider the SO of sintered flue gas$_2$and NO$_x$Collaborative emission reduction is the main direction of scientific research in the future. Some domestic iron and steel enterprises have adopted activated carbon or activated coke technology, but because of the high investment cost, it has not been widely used. Therefore, how to reduce the investment and operation cost of comprehensive treatment technology of flue gas pollutants and further improve the adsorption effect of activated carbon or activated coke is the key to the wide application of existing technology. Combined with the existing terminal treatment technology will be an important direction in the future.

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