ISSN 2176-3135

EFFECT OF PARTICLE MORPHOLOGY OF IRON ORE ON MOISTURE SEGREGATION IN SINTER MIXTURE[1]

Guo-liang Zhang[2]
Sheng-li Wu[2]
Juan Zhu[2]
Yong-zhi Wang[2]
Xin-liang Liu[2]
Shao-guo Chen[2]
Jia-xin Fan[2]

Abstract

Suitable content and distribution of sinter mix moisture plays an important role in promoting particle growth and improving granulated particle strength. Previous researches mainly concerned the effects of water absorption and saturated water amount of iron ore on moisture addition. However, rare researches covered the effect of particle morphology of iron ore on moisture segregation in sinter mixture. By application of immersion method and capillary water suction method, experiments are conducted to study the effects of porosity, size distribution and particle shape on water absorption rate. Moreover, water absorption characteristics of iron ore at different stages are investigated, thus relationship between particle morphology and moisture segregation is obtained, and moisture segregation mechanism is explored. The results are as follows: (1) Iron ore which has larger porosity, smaller particle size and plate structure has larger water absorption rate, thus this typical iron ore can obtain more segregated water. (2) The process-water absorption rate of iron ore is mainly influenced by particle shape in the earlier stage while affected mainly by porosity in the later stage. (3) The size and amount of capillary pores among iron ore particles are mainly determined by particle morphology of iron ore which produces the different capillary effects and all these results in the moisture segregation.

Key words: Iron ore sinter; Mixture granulation; Particle morphology; Moisture Segregation.

[1] *Technical contribution to the 6th International Congress on the Science and Technology of Ironmaking – ICSTI, 42nd International Meeting on Ironmaking and 13th International Symposium on Iron Ore, October 14th to 18th, 2012, Rio de Janeiro, RJ, Brazil.*

[2] *State Key Laboratory of Advanced Metallurgy and School of Metallurgical and Ecological Engineering, University of Science and Technology Beijing, Beijing, China.*

ISSN 2176-3135

1 INTRODUCTION

With the progressive consumption of iron ore resources in recent years, there has been an increase in the quantity of some inferior iron ores as Marra Mamba ore used in the raw material mixture. These kinds of iron ores have inferior granulation properties due to their higher water absorption, leading to insufficient granulation moisture.[1-5] In older to solve this problem, scholars did a lot of researches. Matsumura[6,7] and LV Xuewei[8] studied the optimum moisture content for granulated particle of iron ore. Maeda studied the effect of property of iron ore and granulation condition on the strength of quasi-particle.[9,10] Iveson studied the contact angle of iron ores.[11-13] And all these studies focus on the water absorption of iron ore, but in the production process the adding moisture time is too short for the iron ores to get enough water, so the water absorption in a certain time and as a result of moisture segregation are more important.
Then, in this study, As the fundamental study for understanding effect of particle morphology of iron ore on moisture segregation, the water absorption rate of single particle and multi-particle iron ore were measured by the water absorption testing method using four kinds of iron ores with different particle morphology, such as particle porosity, particle size and particle shape. In addition, some techniques were introduced to solve the problem of moisture segregation caused by the difference between various iron ores.

2 EXPERIMENTS

2.1 Definition

Water absorption rate, in present study, is defined as the water content which can be hold in and among the iron ore particles of unit volume in unit of time. The equation used to calculate the water absorption rate can be expressed as:

$$V = \frac{M}{T} \qquad (1)$$

Where V , g/min; M , g; T , min, individually, refer to the water absorption rate, mass of water absorbed by the iron ores, and the time. The water which touches the single particle or multi-particles of iron ore can be absorbed into the porosity of single particles of iron ore or into the void between the multi-particles by the capillary force. So the porosity of single particle and void between multi-particles play an important role of water absorption rate.

2.2 Samples

4 kinds of iron ores will be used in this study. At first, all these 4 kinds of iron ores were dried in an air oven at 373K for 24 hours. Then sieving was made for these 4 kinds of iron ores and getting 8 kinds of size distribution of each kind of iron ore. Table 1 shows the chemical composition of iron ores used in this study. Here Ore A is limonite iron ore from Australia, and Ore B is Marra Mamba iron ore from Australia, and Ore C and Ore D are hematite iron ores, from Brazil and South Africa respectively. Figure 1 shows the particle shape of iron ores, here the particle shape of Ore A and Ore B are blocky

ISSN 2176-3135

structure with obvious edges, Ore C is plate structure with obvious edges, Ore D is also blocky structure, but without obvious edges.

Table 1. Chemical composition (weight %) of iron ore samples

Ores	TFe %	SiO_2 %	Al_2O_3 %	CaO %	MgO %	LOI %
Ore A	58.26	5.53	1.44	0.04	0.10	9.82
Ore B	61.44	3.24	2.03	0.02	0.10	6.38
Ore C	65.35	1.57	1.26	0.02	0.08	2.16
Ore D	65.68	3.27	1.18	0.10	0.02	0.61

Table 2 shows the size distribution of iron ores, here the size which used are 6.30~8.00mm, 5.00~6.30mm, 3.15~5.00mm, 2.00~3.15mm, 1.00~2.00mm, 0.50~1.00mm, 0.25~0.50mm and 0.15~0.25mm respectively.

Table 2. Size distribution (weight %) of iron ore samples

Ores	>8	6.30~ 8.00	5.00~ 6.30	3.15~ 5.00	2.00~ 3.15	1.00~ 2.00	0.50~ 1.00	0.25~ 0.50	0.15~ 0.25	<0.25
Ore A	14.67	7.21	6.59	14.14	12.03	17.08	14.65	7.63	3.58	2.42
Ore B	4.79	6.35	6.64	12.91	9.58	11.48	11.40	13.29	13.95	9.60
Ore C	8.78	4.50	6.32	12.59	9.02	10.34	10.01	12.33	12.69	13.43
Ore D	13.19	23.03	35.10	17.63	2.53	1.49	0.78	1.29	3.85	1.12

Figure 1. Shape of iron ore particles

2.3 Porosity

Single particle's porosity was measured so as to exclude the influence of void between multi-particles, the particle size is 6.30~8.00mm. The method for porosity of single particle iron ore is gas adsorption method, with the N_2 at the room temperature.

ISSN 2176-3135

2.4 Water Absorption Rate of Single Particle Iron Ores

Figure 2 (a) shows the schematic diagram of the penetrate progress of the water into the pore by the effect of capaliry force. There are 3 kinds of pores in the particle, P_1 is open cylindrical pore, with 2 entrances, P_2 is closed cylindrical pore with 1 entrances, P_3 is the pore which kept in the particle with no entrance. W is the water. Firstly, all these 3 kinds of pores are full of air. Secondly, water will permeates in the P_1 and P_2 gradually by the capillary force, but the water can't fully fill the pore at the beginning, and produces the residual pore P_4. Thirdly, the air remaining in the P_4 is squeezed out of the pore by the water, and the whole particle is covered by a layer of water film.
Figure 3 (a) shows the schematic of instrument of measurement named immersion method of water absorption rate of single particle. As shown in Fig. 3 (a), firstly, the single particle was grinded to cube with same size and dried 24 hours in the oven at 375K. Then weigh, record the original weight of the particle, after that, put the particle in the water and record the absorption time, finally, take out the particle and record the final weight, and calculate the water absorption rate.

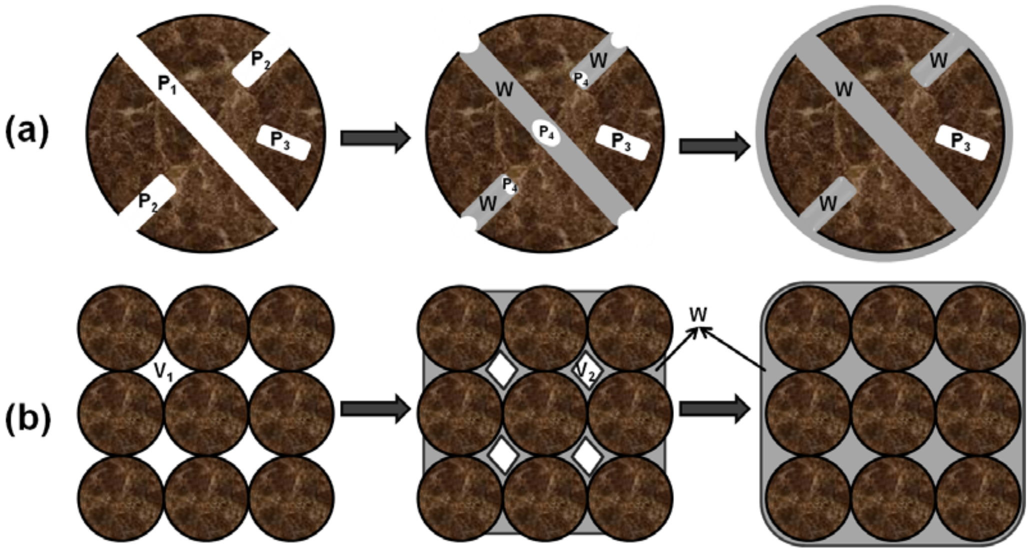

Figure 2. Schematic diagram of the pore/void on the water absorption rate

2.5 Water Absorption Rate of Multi-Particle Iron Ores

Figure 2 (b) shows the schematic diagram of the effect of the void on the water absorption rate of multi-particle iron ores. W is the water. V_1 is the void between multi-particles. Firstly, the air fills the void. Secondly, some water permeates in the void gradually by the capillary force, but some air sill remained in the water, it's too late for them to escape the void because the high water absorption rate, and produces the residual void V_2.Thirdly, water fills the void and the whole particles are covered by a layer of water film.
Figure 3 (b) shows the schematic of instrument of measurement named capillary water suction method of water absorption rate of multi-particle of iron ore. As shown in Fig. 3 (b), firstly make sure the glass tube and capillary glass tube are full of water. Then pour

ISSN 2176-3135

the multi-particle of iron ore into the glass funnel and smooth the samples surface quickly, and the water will be absorbed in the multi-particle of iron ore by capillary force, at the same time, record the time and scale marked on the capillary glass tube. Just as a slight clarification, make sure the volume of multi-particle sample in each group is the same.

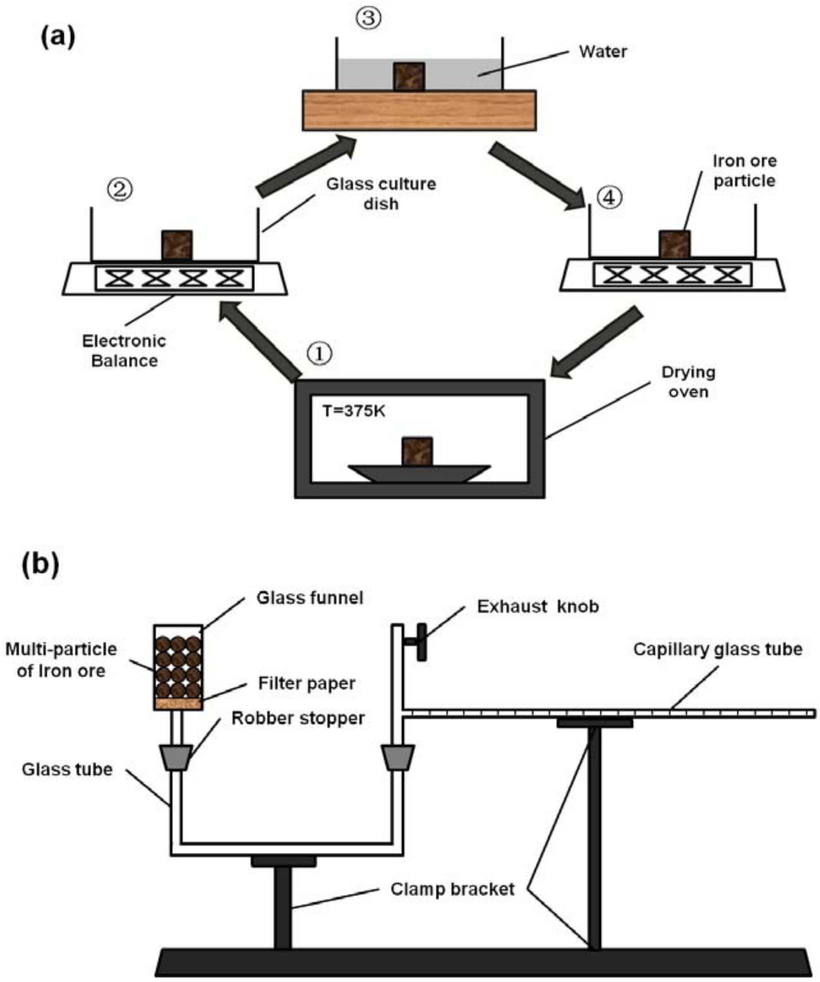

Figure 3. Schematic of instrument for measurement of water absorption rate. (a) Single particle. (b) Multi-particle.

3 RESULTS

3.1 Porosity

Figure 4 shows the porosity of the 4 kinds of iron ores. As shown in Fig. 4, it was found that the porosity of iron ores decrease in the order of Ore A, Ore B, Ore C and Ore D.

ISSN 2176-3135

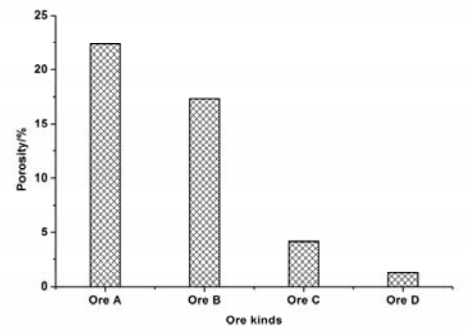

Figure 4. Porosity of iron ores

3.2 Water Absorption Rate of Single Particle of Iron Ores

Figure 5 shows the water absorption rate of 4 kinds of single particle iron ores at different water absorption time. The particle size of iron ore used in figure (a), (b), (c) and (d) are 6.30~8.00mm, 5.00~6.30mm, 3.15~5.00mm and 2.00~3.15mm respectively. As shown in Fig. 5, all the water absorption rates of 4 kinds of iron ores diminish quickly with the water absorption time, until near 0.

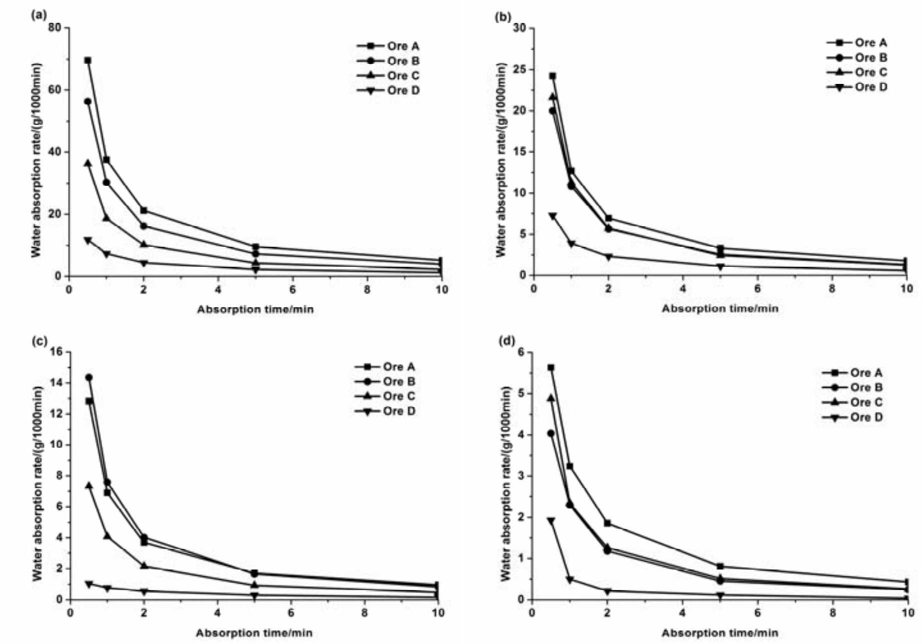

Figure 5. Water absorption rate of single particle iron ore

ISSN 2176-3135

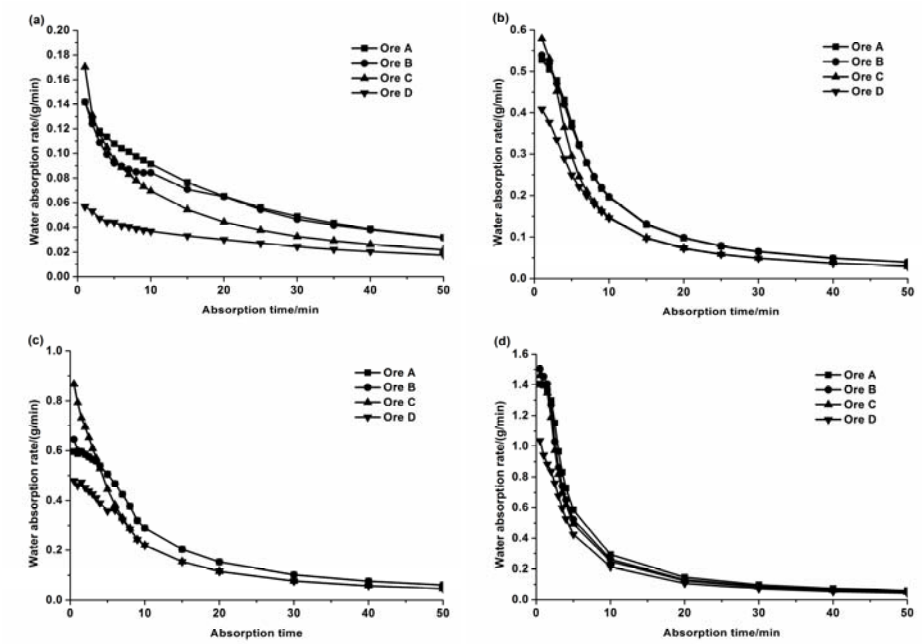

Figure 6. Water absorption rate of multi-particle iron ore

3.3 Water Absorption Rate of Multi-Particles of Iron Ores

Figure 6 shows the water absorption rate of 4 kinds of multi-particle iron ores at different water absorption time. The particle size of iron ore used in figure (a), (b), (c) and (d) are 1.00~2.00mm, 0.50~1.00mm, 0.25~0.50mm and 0.15~0.25mm respectively. As shown in Fig. 6, all the water absorption rates of 4 kinds of iron ores diminish quickly with the water absorption time, until near 0.

4 DISCUSSION

4.1 Influence of Porosity on Water Absorption Rate

Figure 7 (a) shows the relationship between water absorption rate and porosity. As shown in Fig. 7 (a), the water absorption rate has positive linear correlativity with the porosity, and the linear correlation coefficient is 0.8746. Since the water films covered particles are approximately the same with the same particle size, so most of the water absorbed in the iron ore particle is kept in the pores of particles as shown in Fig. 2 (a) by the capillary force.

ISSN 2176-3135
ICSTI
6th International Congress on the Science and Technology of Ironmaking - ICSTI
42th Ironmaking and Raw Materials Seminar/ 42º Seminário de Redução de Minério de Ferro e Matérias-primas
13th Brazilian Symposium on Iron Ore/ 13º Seminário Brasileiro de Minério de Ferro

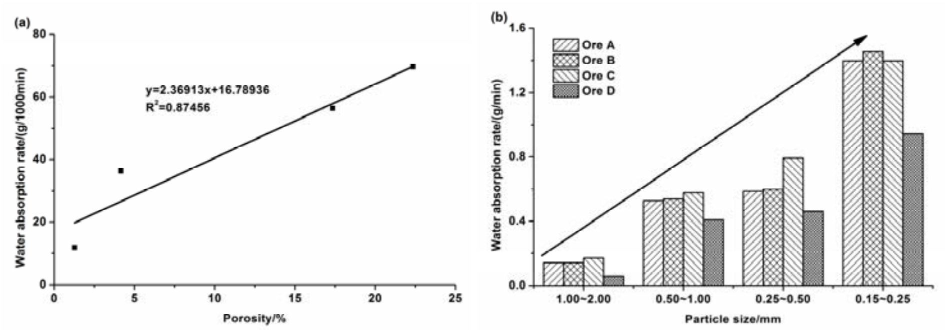

Figure 7. (a) Relationship between water absorption rate and porosity. (b) Relationship between water absorption rate and Particle size of single particle iron ore.

4.2 Influence of Particle Size on Water Absorption Rate

Figure 7 (b) shows the water absorption rate of multi-particle iron ores with the water absorption time is 1 min. As shown in Fig. 7 (b), Ore A and Ore B and Ore C have the bigger water absorption rate, and Ore D's water absorption rate is smaller. Moreover, from Fig. 7 (b), it was found that the water absorption rate of samples become big in the order of particle size of 1.00~2.00mm, 0.50~1.00mm, 0.25~0.50mm and 0.15~0.25mm. Since the smaller of particle size, the bigger specific surface area of the particle, at the same time, just as shown in Fig 2 (b), the capillary force is bigger just because the void among particles is more fine, so the water absorption rate increases with the decrease of the particle size.

4.3 Influence of Particle Shape on Water Absorption Rate

Taking the Ore A and Ore C as example, figure 8 (a) and (b) show the water absorption rate of multi-particle Ore A and Ore C at 1 min and 10 min respectively. From the Fig. 8 (a), it can be found that the water absorption rates of Ore A are smaller than the water absorption rates of Ore C, but as shown in the Fig. 8 (b), the water absorption rates of Ore A are bigger than the water absorption rates of Ore C.
Regarding both the results shown in Fig. 8 and the results shown in Fig. 5, it is supposed that for the multi-particle iron ore, if the particle size is same, at the beginning of absorption, the Ore C with plate structure has higher water absorption rate because the void size void number between plate structure particles are finer and more than the void between blocky structure particles, it has bigger capillary force, that is to say, the particle shape is more important role at the beginning. But at the later stage, more water permeates into the void and then into the porosity, so the Ore A with bigger porosity has bigger water absorption rate, in other words, the porosity of particle plays a bigger role at the later stage.

ISSN 2176-3135

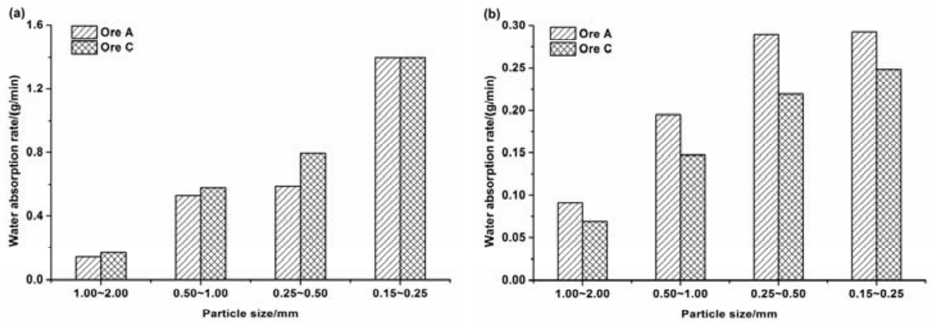

Figure 8. Water absorption rate of multi-particle Ore A and Ore C. (a) Absorption time is 1 min; (b) Absorption time is 10 min.

4.4 Effect of Water Absorption Rate on Moisture Segregation in Sinter Mixture

In practical production, normally, all the iron ores were mixed together and then wetted, the probability and time contacting water for each kind of ore is same, and the adding moisture is not enough usually, so the ore which has bigger water absorption rate will get more moisture, if the volume of moisture it got is suitable for granulation, the quasi-particle made will be perfect, on the contrary, if the volume of moisture it got is too much for granulation, the quasi-particle made will be too sticky to affect permeability, and it will also cause moisture waste. For the ore with small water absorption rate, it can't get enough moisture for granulation, and it can't get good quasi-particle.
Some techniques maybe can solve the problem mentioned above, when ore with high water absorption rate and ore with small water absorption rate are used as the nuclei particles and fine particles respectively, the good quasi-particle will be got, just because the fine particles can get more moisture because the smaller particle size.

5 CONCLUSIONS

As the fundamental study for getting effect of particle morphology of iron ore on moisture segregation, the water absorption rate of single particle and multi-particle iron ore were measured by the water absorption testing method using four kinds of iron ores with different particle morphology. The results obtained are follows:

- the water absorption rate diminishes quickly and near 0 finally with the absorption time increase.
- the particle morphology plays an important role on the water absorption rate of different iron ores. Iron ore which has larger porosity, smaller particle size and plate structure has larger water absorption rate thus this typical iron ore can obtain more segregated water.
- the size and amount of capillary pores among iron ore particles are mainly determined by particle morphology of iron ore which produces the different capillary effects and all this results in the moisture segregation.
- the particle shape and porosity of iron ore play the different role at different stage in the water absorption process. At the beginning of water absorption process, the water absorption rate of iron ore is mainly influenced by particle shape in the earlier stage while affected mainly by porosity in the later stage.

ISSN 2176-3135

- the moisture segregation caused by different water absorption rate of iron ore effects the result of granulation in a way. Maybe the selective granulating technique is a possible means in solving this problem.

REFERENCES

1 NEWITT. D. M, CONWAY-JONES. J. M. A conteribution to the theory and practice of granulation. *Trans. Inst. Chem. Eng.,* v. 36, p. 422-442, 1958.
2 KAPUR P.C. Balling and granulation. *Adv. Chem. Eng*., v. 10, p. 55-123, 1978.
3 WATER. A. G, LITSTER. J. D, NICOL. S. K. A mathematical model for the prediction of granule size distribution for multicomponent sinter feed. *ISIJ Int*., v. 29, p. 274-283, 1989.
4 MAKI T, SEKIGUCHI I. Study for evaluation and optimization of iron ore granulation with consideration of dynamics and particle conditions. *ISIJ Int*., v. 49, p. 631-636, 2009.
5 MATSUMURA M, KAWAGUCHI T. Effect of moisture distribution of sinter mixture on granulation particles. *Tetsu-to-Hagané*, v. 87, p. 290-297, 2001.
6 MATSUMURA T, MIYAGAWA K, YAMAGATA Y. Influence of the nuclei particle properties on granulatility of marra mamba iron ore by high speed agitating mixer. *ISIJ Int*., v. 45, p. 485-491, 2005.
7 MATSUMURA T, MAKI T, AMANO S, etc. Effect of moisture absorption behaving on optimal granulation moisture value of sinter raw material. *ISIJ Int*., v. 49, p. 618-624, 2009.
8 LV S.W, BAI C.G, QIU G.B, etc. Moisture capacity: definition, measurement, and application in determining the optmal water content in granulation. *ISIJ Int*., v. 50, p. 695-701, 2010.
9 MAEDA T, NISHIOKA K, SHIMIZU M. Effect of granulation condition and propertity fo raw material on strength of granulated particle by tumbling granulation. *ISIJ Int*., v. 49, p. 625-630, 2009.
10 MAEDA T, FUKUMOTO C, MATSUMURA T, etc. Effect of adding moisture and wettability on granulation of iron ore. *ISIJ Int*., v. 45, p. 477-484, 2005.
11 IVESON S.M, HOLT S, BIGGS S. Contact angle measurements of iron ore powders. *Colloids Surf. A: Physicochemical and Engineering Aspects*, v. 166, p. 203-214, 2000.
12 IVESON S.M, HOLT S, BIGGS S. Advancing contact angle of iron ores as a function of their hematite and goethite content: implication for pelletising and sintering. *Int. J. Miner. Process*, v. 74, p. 281-287, 2004.
13 IVESON S.M, RUTHERFORD K.F, BIGGS S. Liquid penetration rate into submerged porous particles: theory, experimental validation and implications for iron ore granulation and sintering. *Trans. Inst. MIN. Metall. C*, v. 110, p. 133-143, 2001.