Research on the Enhanced Preparation Process for Pellets with Sea Sand Vanadium Titanomagnetite Smelting in the Blast Furnace

Zhen-xing XING¹,a, Jin-sheng Liu¹,b, Zhuang Huang¹,c, Gong-jin CHENG¹,d, He YANG¹,e, Xiang-xin XUE¹,f

¹School of Metallurgy, Northeastern University, Shenyang 110819, 
(azhxing_x@163.com, b1910515@stu.neu.edu.cn, c1810535@stu.neu.edu.cn, 
dchenggg@smm.neu.edu.cn, eyangh@smm.neu.edu.cn, fxuexx@mail.neu.edu.cn)

Abstract—The sea sand vanadium titanomagnetite has coarse particles, small specific surface area, and great difficulty in agglomeration process. It is difficult for ironmaking enterprises to use it as an ironmaking raw material in large quantities. In this paper, the different methods were adopted to optimize the pellet performance indexes of sea sand vanadium titanomagnetite in order to increase the usage of SSO. The effects of adding ordinary iron ore powder, vanadia-titania fine powder and ball milling pretreatment of SSO on the preparation process of pellet were studied, and the performance indexes of pellet were analyzed. The results showed that the proportion of unground SSO in pellets was up to 40%. The experimental results provided some reference methods to improve the dosage of SSO.

1. Introduction
Vanadia-titania magnetite is a kind of multi-symbiotic iron ore mainly composed of iron, accompanied by vanadia-titania and various elements, and it is also a kind of mineral resources with large reserves and wide distribution. China is the first country in the world to realize blast furnace smelting of vanadium titanomagnetite. In recent years, the high-quality iron ore are gradually decreasing, and the prices of iron ore are rising, which forces ironmaking enterprises to try to use the sea sand vanadium titanomagnetite resources with low price and high comprehensive utilization value [1].

Sea sand vanadium titanomagnetite (SSO) is a complex iron ore resource. There are deposits distributed in Japan, Indonesia, Australia, and New Zealand, which are rich in reserves and easy to be mined [2-3]. Sea sand vanadium titanomagnetite is regular particle shape, smooth and dense surface, and coarse particle size. SSO is poor ball milling performance and pelletizing performance, and it is difficult to granulate in the process of pelletizing [4-6].

According to the particularity of SSO particles, this study attempts to improve the proportion of SSO in the pellet preparation process. The enhanced preparation process of pellet was studied by disc pelletizer, and the performance of pellets were tested and analyzed.

2. Materials and Methods

2.1. materials
The materials mainly include sea sand ore (SSO), Sijiaying (SJY), Yuantong 14 (YT14) and oukong powder (OKP), and the binder is bentonite. As shown in Table 1 and Table 2, The experimental raw
materials were quantitatively analyzed by ICPAES and XRF. The total iron content of SSO was 58.36 wt.%, which belongs to a vanadium titanomagnetite. The total iron content of SJY and YT-14 was 65.29 wt.% and 66.27 wt.%, respectively. The total iron content of OKP was the highest, which was 68.32 wt%. The content of SiO₂ in bentonite was up to 44.88 wt.% in Table 2.

Table 1 Chemical composition of materials/ wt.%

| composition | TFe   | FeO   | SiO₂ | CaO  | MgO  | Al₂O₃ | TiO₂ | V₂O₅ | LOI  |
|-------------|-------|-------|------|------|------|-------|------|------|------|
| SSO         | 58.36 | 28.23 | 3.27 | 1.15 | 2.88 | 3.33  | 6.95 | 0.47 | 0.14 |
| SJY         | 65.29 | 17.99 | 6.72 | 0.22 | 0.42 | 0.42  | 0.12 | 0.03 | 0.73 |
| YT-14       | 66.27 | 24.77 | 1.83 | 0.69 | 0.88 | 1.41  | 2.48 | 0.29 | 0.66 |
| OKP         | 68.32 | 27.04 | 4.27 | 0.13 | 0.3  | 0.32  | -    | -    | 0.46 |

Table 2 Chemical composition of bentonite/ wt.%

| composition | SiO₂ | CaO  | Al₂O₃ | Na₂O | K₂O |
|-------------|------|------|-------|------|-----|
| content     | 44.88| 4.08 | 12.88 | 4.18 | 1.03|

2.2. Particle characteristics analysis of SSO

As shown in Fig. 1, the phase composition of SSO was analyzed by XRD. SSO phases were magnetite, hematite, and ilmenite. Fig. 1(b) and Fig. 1(c) is the macro-morphology and micro-morphology of SSO. The particles shape of sea sand ore was relatively regular, showing a spherical or ellipsoid shape, and the particle texture was smooth and shiny.

Fig. 1 The XRD diagram and morphological characteristics of SSO

The Table 3 is the particle size composition and BET of SSO. The particles of SSO were relatively coarse, and the specific surface area was only 0.3 m²/g, which shows that the pelletizing performance of SSO was poor.

Table 3 Particle size compositions and BET of SSO

| Material | Particle size composition /mm | BET /m²/g |
|----------|------------------------------|-----------|
| SSO      | +0.074 0.038-0.074 -0.038    | 0.30      |
2.3. Experimental methods

The pellets were oxidatively roasting in a muffle furnace. 12 green pellets were made to fall freely from 500 mm height, and it is specified that the falling times until there is a crack in the pellet is the falling strength index, and recorded as the falling strength of the pellet, the unit is times/pellet. 12 green pellets were measured by pressing method, and the force on the green pellets when cracks appeared was recorded as the compressive strength of the pellets, the unit is N. The pellet compressive strength was tested according to the national standard GB/T 14201-1993.

3. Optimization of pellets preparation process

3.1. Preparation of enhanced pellets with ordinary iron ore powder

In view of the problems of coarse particles, small specific surface area and high V and Ti content of sea sand ore, SJY and OKP with small particle size and easy pelletizing were selected as ordinary iron ore powder and mixed with sea sand ore. The effect of ordinary ore powder on pellet was shown in Fig. 2.

![Fig.2 Effect of ordinary iron ore powder on pellets properties](image)

According to results, the dosage of SJY and binder were kept unchanged at 50 wt.% and 1.5 wt.%, respectively. With the dosage of SSO increased gradually to 40 wt.%, the compressive and falling strength of pellet decreased first and then increased. The oxidized pellets compressive strength first increased and then decreased. When the SSO was 40 wt.%, the falling strength reached 32 times/pellet. Currently, the compressive strength was 11 N and that of oxidized pellets was 3377 N.

3.2. Preparation of enhanced pellets with vanadia-titania fine powder

SJY and YT-14 were selected as vanadia-titania fine powder and mixed with SSO to prepare pellet. The effect of vanadia-titania fine powder on the properties of pellets was shown in Fig. 3.
According to results, with the addition amount of SSO from 10 wt.% to 40 wt.%, the falling strength of pellet increased, while the compressive strength of pellet decreased gradually, and the compressive strength of oxidized pellet increased. When the SSO was 40 wt.%, the compressive and falling strength of pellet were 8.41 N/pellet and 28.71 times/pellet respectively, and the oxidized pellets compressive strength 3146 N/pellet. The addition of fine powder had a good mixing effect on the uniform distribution of particle size in pellet, and improved the various performance indexes of pellets. Therefore, the maximum dosage of SSO was 40 wt.%.

3.3. Preparation of enhanced pellets by ball milling pretreatment

The SSO was pretreated by ball milling in the experimental process, and the pellets were prepared by adding unground SSO and SJY. The dosage of SJY and binder remained unchanged at 40 wt.% and 1.5 wt.% respectively, the dosage of ungrounded sea sand ore from 0 wt.% to 60 wt.%, the dosage of ball milled sea sand ore gradually decreased from 60 wt.% to 0 wt.%. The effect of ball milling pretreatment on the properties of pellet was shown in Fig. 4.

According to the results in Fig. 4, as the amount of unground SSO increased, the compressive and falling strength of pellet were 9 N and 5 times/pellet, respectively. The oxidized pellets compressive strength showed a trend of increasing gradually. When unground SSO was 40 wt.%, the oxidized pellets compressive strength reached 2665 N/pellet, which met the application standard of pellets.
4. Conclusions

In view of the problems such as coarse particles and small specific surface area of sea sand vanadium titanomagnetite, the appropriate dosage of SSO in pellet preparation process was studied by disc pelletizer.

(1) It was found that the performance indexes of pellet were enhanced to a certain extent by adding ordinary iron ore powder, vanadia-titania fine powder and ball milling pretreatment, and the results showed that the pellet with 40 wt.% unground SSO still met the application standard of pellets.

(2) The enhanced preparation process of pellet was studied, the SSO dosage in pellet was improved, which provided data reference for enterprises to use SSO in large quantities.

Acknowledgments

The authors are thankful to the National Natural Science Foundation of China (Grant No. U1908226).

References

[1] H.G. Du. (1996) Principle of smelting vanadium-titanium magnetite in the blast furnace, Science Press, Beijing, China.
[2] Z.X. Xing. (2019) Basic experimental research on preparation of oxidized pellets with sea sand mine [D]. Shenyang: Northeastern University.
[3] A. Podder. (2021) Study of Humidity on Moisture Transfer Characteristics in Iron Ore Sintering. Trans Indian Inst Met, 74(6): 1479-1487.
[4] Z.X. Xing, G.J. Cheng, Z.X. Gao, et al. (2020) Optimization of experimental conditions on preparation of oxidized pellets with New Zealand Sea sand ore. Metall. Res. Technol., 117: 411-421.
[5] Z.X. Xing, G.J. Cheng, Z.X. Gao, et al. (2021) Effect of Incremental Utilization of Unground Sea Sand Ore on the Consolidation and Reduction Behavior of Vanadia–Titania Magnetite Pellets. Metals, 11(2): 269-286.