ISCRE25
FLORENCE 2018
BRIDGING
SCIENCE & TECHNOLOGY
The 25th International Symposium
on Chemical Reaction Engineering
20-23 May 2018
Florence, Italy
www.aidic.it/iscre25

Study on the reduction kinetics of iron ore powder at high temperature with in situ visual technique

Zhongjie Shen[1,2], Qinfeng Liang[1,2], Jianliang Xu[1,2], Kuangfei Lin[3], Haifeng Liu[1,2,*]

1 Key Laboratory of Coal Gasification and Energy Chemical Engineering of Ministry of Education, East China University of Science and Technology, P. O. Box 272, Shanghai 200237, PR. China;
2 Shanghai Engineering Research Center of Coal Gasification, East China University of Science and Technology, P. O. Box 272, Shanghai 200237, PR. China;
3 State Environmental Protection Key Laboratory of Environmental Risk Assessment and Control on Chemical Process, East China University of Science and Technology, Shanghai 200237, PR. of China.
**Corresponding author: hfliu@ecust.edu.cn*

Highlights

- Evolution of surficial morphology of iron power in the CO atmosphere were observed.
- Reduction of iron ore powder was also analyzed by Raman spectroscopy for the products.
- Reduction degree versus reduction time at different gas flow rates were given.
- Reduction intrinsic kinetics parameter of iron ore powder at high temperature were given.

1. Introduction

With the rapid growth of world steel production, coking coal also known as metallurgical coal is becoming scarce worldwide with bringing the serious environmental pollution. Direct reduced iron gradually has become an important industrial material as a compensation of the shortage of high quality steel scrap. Fruehan previously have studied the reduction rate of iron oxide for different solid reductants [1]. The reduction rate depended on the carbon gasification rate below 1100 ℃ while the reduction rate above 1200 ℃ was controlled by the combination of carbon gasification rate and the reduction rate of CO to iron oxides. Man and Feng found the reduction process is three-dimensional phase-boundary controlled in H_2 and CO atmosphere. [2] The rate of reduction in the presence of H_2 was significantly higher than in the CO atmosphere above 900 ℃. 1100 ℃ and hydrogen atmosphere was optimum for the reduction of both iron ore concentrate and red mud pellets in the experimental conditions. Kuila et al. [3] studied the kinetics of hydrogen reduction of magnetite ore fines. The reduction of magnetite fines took place in two stages: Fe_3O_4 to FeO and FeO to Fe. Each stage was controlled by pore diffusion kinetics. Piotrowski et al. [4] also studied the kinetics of hematite (Fe_2O_3) to wiistite (FeO) reduction and estimated the kinetics parameters. However, the reduction of iron ore powder at high temperature was seldom referred in the literatures due to the difficulty in the experiment. This study applied the in situ technique to study the reduction iron ore powder at high temperature with the combination of Raman spectroscopy and scanning electron microscope and energy spectrum analysis.

2. Methods

To study the reduction kinetics of iron ore powder at high temperature, in situ experiments were carried out on the high temperature stage microscope (HTSM). The detailed description of the HTSM was referred in the previous study of Shen et al. [5] The iron ore powders were spread on the sapphire slip and heated to different high temperatures (1300 ℃, 1400 ℃ and 1500 ℃) at the heating rate of 100 ℃/min. The sample was held for 5 min in the Ar atmosphere. Then CO replaced Ar for the reaction gas and meanwhile the microscope camera system started and recorded the complete reduction process of iron ore powder. The reduction products of iron ore powder was analyzed by using SEM-EDS and Raman spectroscopy for the morphology and chemical compositions.

3. Results and discussion

The evolution of the morphology of the iron ore powder showed that with different sizes the surface of the iron ore powder become smooth and bright with the reaction of CO. With the increase of gas flow and the

decrease of particle size, the reduction degree increased similarly between the adjacent conditions and the effects of internal/external diffusion on the reduction were removed. Study of the intrinsic kinetics showed that the reduction degree increased with increasing the reduction temperature and time, which is given in Figure 1. The reduction rate increased and then decreased with the reduction degree at lower temperature while at high temperature the reduction rate decreased with the reduction degree. Reduction of iron ore powder was also analyzed by Raman spectroscopy for the products. The average value of the activation energy calculated from the experimental data was 109.62 KJ/mol. The mechanism analyses from the literatures for the activation energy were about 103.33KJ/mol, which proved the availability and accuracy of the intrinsic kinetics research method.

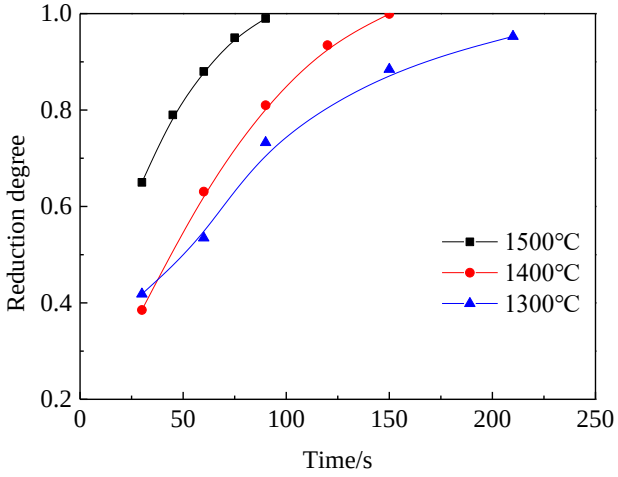

Figure 1. Reduction degree of iron ore powder at different high temperatures.

4. Conclusions

The reduction kinetics of iron ore powder at high temperature were studied in this study by using the high temperature stage microscope. The evolution of the morphology of the iron ore powder with different sizes were observed and compared at different temperatures. The effects of internal/external diffusion on the reduction were removed and the intrinsic kinetics were speculated from the experimental results. The reduction degree increased with increasing the reduction temperature and time. The reduction rate increased and then decreased with the reduction degree at lower temperature while at high temperature the reduction rate decreased with the reduction degree. The activation energy calculated from the experimental data was similar with the mechanism analyses from the literatures, which proved the availability and accuracy of the intrinsic kinetics research method in this study.

References

[1] R.J. Fruehan. Metall. Trans. B. 8 (1977) 279-286.
[2] Y. Man, J.X. Feng. Powder Technol. 301 (2016) 674-678.
[3] S.K. Kuila, R.Chatterjee, D. Ghosh. Int. J. Hydrogen Energ. 41 (2016) 9256-9266.
[4] K. Piotrowsk, K. Mondal, T. Wiltowski, P. Dydo, G. Rizeg, Chem. Eng. J. 131 (2007) 73–82.
[5]
[6] Z. Shen, Q. Liang, J. Xu, B. Zhang, D. Han, H. Liu, Combust. Flame, 166 (2016) 333-342.

Keywords
iron ore powder; reduction; high temperature; intrinsic kinetics.

If you submit a paper to Gianni Astarita Young Investigator Award, please append a short CV to this paper