RESEARCH ON HIGH TEMPERATURE PROPERTIES OF IRON ORE MATERIALS

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Abstract
The paper deals with reducibility of metallurgical pellets. They were tested by ISO 4695:2007 to determine their reducibility in CO environment at 950°C and ISO 4696-2:2007 to determine their disintegration index after reduction at 550°C. The paper presents the results of reduction process. It compares them with reducibility of other material such as iron ore and sinter. The paper interprets the effect of reduction on phase composition of pellets and the content of bounded water. The thermoplastic properties present physic-chemical changes of feedstock during its descent in the shaft of blast furnace aggregate. The mechanical solidity characterizes the capability of material to be resistant against the pressure, the crash, the fall and the abrasion.

Keywords: iron, pellets, reduction, CO, blast furnace

1 Introduction

There are several properties characterizing the quality of metallurgical material. One of the most important and specific for production process are metallurgical properties of used feedstock. The thermoplastic properties present physic-chemical changes of feedstock during its descent in the shaft of blast furnace aggregate. The mechanical solidity characterizes the capability of material to be resistant against the pressure, the crash, the fall and the abrasion. The reduction defines the behaviour of material in conditions simulating the reductive zone of blast furnace aggregate. It significantly affects on the blast furnace operation and coke consumption [1,2]. The reducibility is important for an estimation of specific coke consumption and a determination of optimal grain size [3]. The reducibility sums the range of chemical, mineralogical, physical and physicochemical properties defining the velocity of iron oxides changes into metal while a reducing agent is affecting. The reducibility is defined by mass depletion caused by oxide reduction into gas. It presents a parameter which easily comparable the purchase of specific raw materials [4-6].

The analysis of effects of ferrous burden materials quality on the parameters of blast furnace process is presented in this paper [7]. The chemical composition, mainly iron content, is the basic quality parameter taken into consideration [8].

2 Experimental Materials and Methods

In VSB – Technical University of Ostrava, Centre ENET the reducibility of metallurgical material supplied from significant ironworks in Ostrava was tested. This device is also possible

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to use for sinter and lump ore testing. There is possible to carry out tests of laboratory sinter prepared on a laboratory sinter pan. The laboratory sinter pan sufficiently simulates conditions, which are presented in the sinter band [9-11]. There were carried out reducibility tests of pellets. The tests were carried out according to standard ISO 4695:2007. The grain size of input material was 10-12.5 mm as it determined by ISO. The sample was isothermally reduced in fixed bed at 950 °C in the environment of reductive gas formed by CO and N_2 [12-15]. These gases were provided for reduction process at gas flow 50 $l \cdot min^{-1}$ in the concentration 40 % of CO and 60 % of N_2. The depletion in oxygen was continuously registered by the thermometer till the grade of reduction reached 65 %. The speed of reduction was calculated according to the rate oxygen/iron = 0.9. Calculation of reduction grade Rt [16, 17]:

$$R_t = \left(\frac{0.111 w_1}{0.430 w_2} + \frac{m_1 - m_t}{m_0 \cdot 0.430 w_2} \cdot 100\right) \cdot 100 \quad (1)$$

where: m_0 [g] sample weight;
m_1 [g] sample weight immediately before the initiation of reduction;
m_t [g] sample weight after reduction;
w_1 [%] content of FeO
w_2 [%] content of Fe

Calculation of reducibility index: The main output of reducibility tests are curves of reducibility grade Rt in the time. According to the standard, characteristics such as time [min] for 30 % and 60 % reduction are considered to be significant. The result is reducibility index expressed in (2) as speed of reducibility [$\% \cdot min^{-1}$] to reach weight rate O/Fe = 0.9.

$$\frac{dR}{dt}\left(\frac{O}{Fe} = 0.9\right) = \frac{33.6}{t_{60} - t_{30}} \quad (2)$$

where: t_{30} [min] time necessary to reach 30 % of reduction grade;
t_{60} [min] time necessary to reach 60 % of reduction grade;
33.6 constant.

The rate O/Fe = 0.9 means reduction of input oxide Fe_2O_3 (rate O/Fe = 1.5) in 40 % of weight sample.

$$1.5 - 0.9 = 0.6 \quad (3)$$

Then

$$\frac{0.6}{1.5} \cdot 100 = 40\%$$

The pellets were tested according to ISO 4696-2 to determine their desintegration after the reduction. The grain size of input material was again 10-12.5 mm. The sample of 500 g was isothermally reduced in fixed bed just at 550 °C in the similar environment of reductive gas formed by CO and N_2 provided at gas flow 15 $l \cdot min^{-1}$ in the concentration 30 % of CO and 70 % of N_2. After 30 minutes' reduction, the sample was cooled by nitrogen and followed by disintegration test in the tumble drum where it was rotated for a total of 900 revolutions at a rate of 30 $r \cdot min^{-1}$. The sample was then hand-sieved with care on 2.8 mm sieve. The retained on the sieve was recorded as m1. Material lost during tumbling and sieveing was considered to be part of the -2.8 mm fraction. The reduction-disintegration index, RDI-$2_{-2.8}$ expressed as percentage by mass was counted from the equation (4) [18]:

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$$RDI\text{-}2_{-2.8} = 100 - \frac{m_1}{m_0} \cdot 100 \tag{4}$$

where: m_0 [g] is the mass of the test portion after reduction and before tumbling
m_1 [g] is the mass of the fraction retained on the 2.8 mm sieve

3 Results

The results of reduction process according to ISO 4695:2007 are presented in **Fig. 1**. It describes the process of mass depletion counted as Rt [%] in relation to the time. The initiation of endothermic dissociation at 250 °C resulted in decrease of heating rate in the retort. The rate increased after a while to the specified temperature because of PC control causing the power input increase.

The RDI-2 $_{-2,8}$ was counted as 5,1%. It was a mass lost during the tumbling. As m_0 was 484.7 g and m1 460 g , it presents almost 25 g. The pellets were carried out with RTG analysis to study their phase composition and its difference between before and after reduction. The results are in **Tab. 1**.

Table 1 Phase composition before and after reduction

Phase	Pellets before reduction	Pellets after reduction
Magnetite	8.11	3.14
Hematite	88.08	33.32
Wüstit	-	
Quartz	3.81	2.33
α-Fe	-	61.22

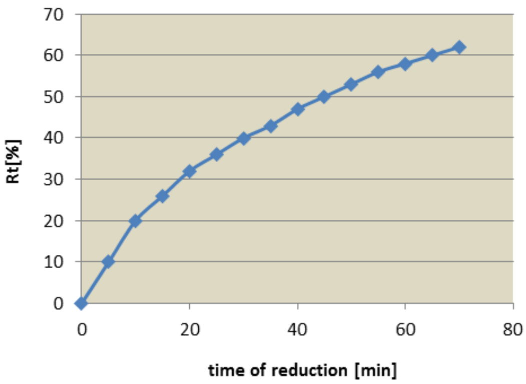

Fig. 1 The course of reduction process

4 Discussion

The pellets were typical of reduction in comparison with other metallurgical materials such as iron ore and sinter. The curve of mass depletion caused by the oxide elimination was at the beginning of reductive gas introduction was similar to mass depletion curve of sinter and iron ore. The tested pellets reached Rt 60 % after 65 minutes meanwhile Rt 60% of sinter was after 53 minutes and iron ore even after 45 minutes. It was confirmed by reduction rate dRt/dt where pellets reached 0.74 %·min-1, sinter 0.82 %·min^{-1} and ore 1.08 %·min^{-1}. **Fig. 2** presents the Rt comparison in the time for all these feedstock materials.

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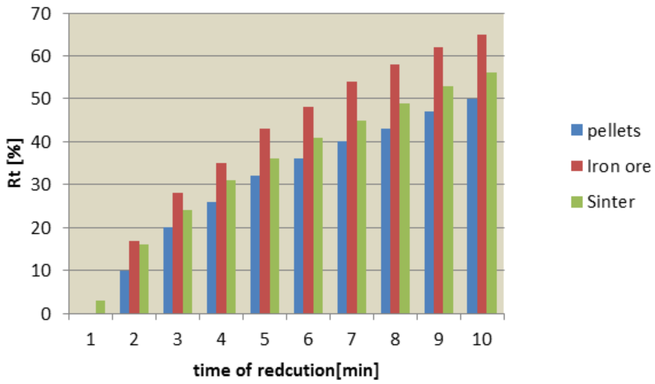

Fig. 2 Comparison of reduction with iron ore and sinter

5 Conclusion

There was studied the reducibility of pellets. Two kinds of tests were carried out. The disintegration after reduction was tested according to ISO 4696-2:2007. The sample of 10-12,5 mm grain size was heated to 550°C then tumbled and studied on mass depletion. The reducibility rate was studied according to OSP 4695:2007. The sample of 10 -12,5 mm grain size was inserted into the retort of testing device and heated by invariable input in the environment of flowing nitrogen to the temperature of 950 °C. The reducibility of pellets was compared with reducibility of iron ore and sinter. There was interpreted the effect of materials on the reduction process.

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