INFLUENCE OF GANGUE CONTENT ON PROPERTIES OF BLAST FURNACE PELLETS

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VPLYV OBSAHU HLUŠINY NA VLASTNOSTI VYSOKOPECNÝCH PELIET

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Abstrakt

Tento príspevok prezentuje výskum zloženia vysokopecných peliet, produkovaných zo železorudného koncentrátu, vyrobených pred a po zavedení vysoko účinnej magnetickej separácie. Pomocou tejto technológie podiel hlušinových zložiek v železorudnom koncentráte sa znížil. Výskum bol robený v kooperácii so závodom Siderit Nižná Slaná, závod zahrňuje ťažbu železnej rudy, úpravňu železnej rudy, obohacovacie zariadenie a peletizačnú linku. Uvedením novej zakúpenej technológie sa produkuje bohatší železnorudný koncentrát s vyšším obsahom železa a s nižším obsahom hlušinových zložiek. Bolo potrebné preskúmať, ako vplýva nižší podiel hlušinových zložiek na vývoj štruktúry a na pevnostné vlastnosti vysokopecných peliet.

Je známe, že hlušinové zložky hrajú pri tvorbe štruktúry skusovených železorudných materiálov, spracovaných vysokoteplotným spôsobom, podstatnú úlohu. Pri vypaľovaní vysokopecných peliet, v oblasti teplôt 1300°C - 1350°C, dochádza k roztaveniu niektorých silikátových zložiek, ktoré môžu v tekutom stave rozpúšťať ďalšie hlušinové zložky aj častice oxidov železa. Pri stuhnutí vytvárajú tieto roztavené zložky základnú vnútornú kostru pelety, ktorá vo veľkej miere ovplyvňuje výslednú pevnosť. Zvýšená bohatosť peliet a teda zvýšený prínos z hľadiska obsahu železa, znamená nižší podiel hlušinových zložiek, teda znížený podiel väzobného materiálu v pelete. Tento fakt sa môže odraziť na pevnosti aj pórovitosti peliet.

Hodnoteniu boli podrobené dve série peliet a koncentrátov. Prvá séria odpovedala železorudnému koncentrátu, používanému pred zavedením vysokoúčinnej magnetickej separácie, druhá séria odpovedala koncentrátu, vyrobnému po zavedení tejto novej technológie.

Abstract

The paper presents research of blast furnace pellets properties, produced from iron ore concentrate, made prior to and after introduction of high efficiency magnetic separation. By this technology contents of gangue components in iron ore concentrate was decreased. The research was made in cooperation with Siderit Nižná Slaná, the factory comprising iron ore mines, iron ore dressing and beneficiation plant and pelletising plant.

Key words: blast furnace pellets, gangue content

1. Role of melt in sintering of iron fines

Thermal processing of iron ores in production of both blast furnace pellets and iron ore sinter production takes place in a lot of consecutive steps: decomposition of hydrates and carbonates, reactions in solid state, oxidation of magnetite, softening and melting of charge. The most decisive process for formation of structure and properties of the product is formation of the melt and its crystallisation. Author of the paper studied in his dissertation thesis conditions of melt formation in sintering of iron ores [1]. The steps, preceding charge softening and melting, can influence the charge composition, e.g. solid state reactions [2], and by this way influence temperature interval of charge melting.

After Majerčák [3], formation, volume and chemical composition of melt in blast furnace pellets are influenced by broad range of factors. He describes function of melt in pellet by three steps. In the first one, melt fills pores and voids in pellets. In the second step fine grains of iron oxides are dissolved in the melt. In the third one pellets are compacted as a result of coalescence of the solid grains.

As mentioned above, melt plays decisive role in formation of final structure of sintered product and its strength properties. Considerable differences exist in conditions of melt formation in production of iron ore sinter and blast furnace pellets. Most of sinters is produced in increased basicity range up to 1,4 $(CaO+MgO / SiO_2+Al_2O_3)$, or even higher (basic sinter). It means basic constituents come to charge and basic melt at lower temperatures is formed. Because of easy formation of melt and its low viscosity, a great deal of charge is dissolved in melt. Crystallisation of melt is very important factor in defining of final structure of iron ore sinter.

In most of blast furnace pellets gangue has acidic character with very low contents of basic constituents. Acidic gangue melts in narrow and higher temperature interval. From this follows only small amount of fine iron oxides grains is dissolved, the volume of the melt is kept small. In final structure of pellet it torms mostly binding phase among grains of iron oxides.

The second factor, influencing formation of melt, temperature conditions in the relates process. In firing of blast furnace pellets temperature is determined by adopted technology and equipments and is in range of 1250°C to 1300°C. On the other side, in sintering of iron ore sinter charge, temperature in very layer of combustion front reaches very high values. Author of the paper in his sintering experiments [4] observed even melting of Pt-PtRh thermocouple in combustion front layer. The same conditions were observed by Nyguist [5].

Orvar Nyguist [5] also studied influence of gangue volume on properties of iron ore sinter and conditions of sintering. He concluded, that some amount of gangue was necessary for production of high quality sinter, which was related to melt formation. The same can be applied to production of blast furnace pellets.

2. Experimental study of blast furnace pellets properties

Two series of iron ore concentrates and pellets made from them, were studied in the work. Series I reflected state prior to introduction of high efficiency magnetic separation, Series II state after introduction. Three kinds of materials were provided by the production factory Siderit Nižná Slaná for experimental study in both Series: iron ore concentrate, green pellets and fired (final) blast furnace pellets. Chemical analysis of final pellets from both Series is in Table 1.

First pelletizability of iron ore concentrates in both series was evaluated. Concentrate was pelletised in laboratory pelletization drum. Four pelletizations were made for each Series, that were different by amount of water used for pelletization. Green pellets were submitted to sieve analysis with the aim to determine their size distribution in four categories: more than 15 mm; 15 to 12.5 mm; 12.5 to 8 mm; less than 8 mm. From measured values mean diameter D_{mean} of green pellets was calculated by formula:

(1)

Table 1 Chemical analysis of pellets, wt %

Green pellets, provided by the factory, were fired in furnace with resistance heating at temperatures 1150°C; 1200°C; 1250°C with holding time 15 and 30 minutes at each temperature. Total six groups of fired pellets were submitted to analysis. Strength of laboratory fired pellets was determined by device of tensile testing machine. Strength was calculated as a mean value of ten analyses. Next, mineralogic surfaces were prepared on pellets, representing each of six groups. Microstructures of pellets were examined and documented under metallographic optic microscope. Porosity of pellets, expressed as pores area on the mineralogic surfaces, was determined by methods of quantitative microscopy.

The same kinds of analysis, analysis of strength, microstructure and porosity, were performed on samples of blast furnace pellets from both Series, produced in pelletization plant of Siderit Nižná Slaná. Moreover, mean size and weight of pellets from both Series were determined. The last analysis made on samples of blast furnace pellets, was test of reducibility, performed at Istanbul Technical University, Faculty of Chemical and Metallurgical Engineering. Parameters of Gakushin reducibility test:

Reduction temperature:	900°C
Reduction time:	180 min
Reducing gas mixture:	30 % CO, 70 % N_2
Sample weight:	500 g

n_o - number of moles of oxygen originally combined with iron in the beginning of the test; from the compositional analysis - constant

n - number of moles of oxygen left combined with iron after test time, t.

3. Discussion of results

3.1 Pelletizability of iron ore concentrate

Pelletizability was evaluated by influence of moisture (water, added for pelletization) on D_{mean} of green pellets, Fig.1. As can by seen from the Figure, D_{mean} increased by higher rate, when pelletizing iron ore concentrate of Series I, original concentrate used prior to introduction of new beneficiation technology. The fact is confirmed by amounts of green pellets in size categories after sieve analysis. When consider pelletization with the highest amount of moisture (16.5 wt % for Series I; 16.2 wt % for series II), 90 % green pellets in series I had diameter 15 mm or more, while most of green pellets in Series II was in size range 12,5 to 8 mm (48,4 %) and in 15 to 12,5 mm (25,8 %). Such size distribution of green pellets in Series II is not suitable from the point of view of final product, blast furnace pellets.

Fig.1 Relationship between Dmean and moisture of pelletized iron ore concentrate

3.2 Properties of green pellets

Relationship between strength of pellets and temperature of firing is in Fig.2, the results are from experimental firing of green pellets in laboratory scale. Only the values related to holding time 30 min were used, as holding time of 15 min was not sufficient for formation of compact structure of pellet. It was clear, that increase of strength and strength values were higher in firing experiments of green pellets from Series I.

Because of not very compact structure, restraining preparation of mineralogic surface, only the pellets, fired at temperatures 1200°C and 1250°C, holding time 30 min, were used for determination of porosity. Relationship between porosity and temperature of firing is in Fig.3. As can by seen from the Figure, porosity increased with temperature of firing in both Series, the values of porosity were considerably higher in pellets from Series I.

Fig.2 Relationship between strength of pellets and firing temperature: laboratory firing of green pellets

Fig.3 Relationship between porosity of pellets and temperature of firing

3.3 Properties of blast furnace pellets

Some properties of blast furnace pellets, provided by production factory Siderit Nižná Slaná, are in Table 2.

Table 2 Properties of blast furnace pellets

As can by seen from the Table, the values of all four parameters are better for Series I when consider their final use in blast furnace process. Very important parameter, monitoring behaviour of pellets in blast furnace, is reducibility. Results of reducibility test are in Fig.4. Also in this case, the rate of oxygen loss and absolute values of reducibility are considerably better for blast furnace pellets from Series I.

Fig.4 Results of reducibility test

3.4 Microstructure of pellets

As was stated above, the pellets from laboratory experiments fired at temperatures 1150°C and 1200°C, were not compact enough for preparation of high quality mineralogic surfaces. Only exception were pellets from Series I, fired 30 min at 1200°C. Their structure had magnetite character with small grains of hematite Fe_2O_3. The structure of pellet from Series I, fired 30 min at 1250°C, is in Fig.5. The structure is very alike to structure of blast furnace pellets from production plant, but distribution of pores sizes is not very even. Fundamental constituent of the structure is magnetite, but small quantity of very fine hematite grains is also observed. The grains of iron oxides are bordered and connected by tiny particles of gangue. The structure of pellet from Series II, fired 30 min at 1250°C, is in Fig.6. The structure is not so compact as the one, presented at Fig.5. Dominating in the structure is magnetibe, but also higher content of hematite grains was observed.

Fig.7 presents structure of the pellet from Series I, produced in production factory. It is clear from the Figure, the structure is compact, homogeneous, pores are uniformly distributed. It consist of magnetic grains and gangue particles, hematite grains are observed very seldom. Fig.8 presents structure of the pellet from Series II, produced in production factory. When compared with Fig.7, the pores, their shape, size and distribution are uneven. Besides magnetite, structure contains also a lot of hematite, as documented in Fig.8.

Fig.7 Structure of blast furnace pellet from Series I, produced in pelletizatin plant

Fig.8 Structure of blast furnace pellet from Series II, produced in pelletizatin plant

4. Conclusions

The paper presents comparison of two kinds of iron ore concentrates and blast furnace pellets, made of them. Both concentrates came from one source, but they were different in compositions, namely in contents of iron bearing and gangue components as a results of introduction of new high efficiency magnetic separation in treatment of mined iron ore. From analysis and laboratory scale experiments followed:

Pelletizability of iron ore concentrate, made prior to introduction of technological change, was far better. Most of green pellets, produced with optimum moisture during pelletization, had size (diameter) 15 mm or more. Pelletization of the concentrate, made after technological change, produced pellets in smaller sizes and returns, portion of pellets with diameter less than 8 mm, were extremely high.

All main parameters, characterizing properties of blast furnace pellets: strength, porosity, diameter, weight, reducibility, were better, when pellets were produced from iron ore concentrate, made before technological change.

Structure of blast furnace pellets made of iron ore concentrate, produced prior to introduction of technological change, was relatively homogeneous, with even distribution of pores. Iron bearing components consisted mainly of magnetite Fe_3O_4. Worse distribution of structural components was observed in blast furnace pellets, made from iron ore concentrate, produced after introduction of technological change. Iron bearing components contained besides magnetite also hematite Fe_2O_3.

By introduction of high efficient magnetic separation composition of iron ore concentrate changed, content of iron - bearing constituents increased and, vice versa, content of gangue components decreased. However, gangue components are substantial for formation of structure and properties of blast furnace pellets. They partialy melt in process of pellets firing and form binding phase in pellets. The solution of the problem lays in setting the beneficiation process, so as to leave a part of very fine gangue particles in iron ore concentrate. Introduction of technology that results in increased Fe content in blast furnace pellets is positive step. The paper shows how important is to study side effects of new technology introduction and to apply connective measures to make the process fully effective.

Literature

[1] Mihok, Ľ.: Sintering Melt and Its Influence on Properties of Iron Ore Sinter, Dissertation Thesis, Faculty of Metallurgy, Košice, 1980

[2] Mihok, Ľ., Majerčák, Š.: Hutnícke listy 1989, 11, pp. 761 -768

[3] Majerčák, Š., Karwan, T.: Theory of Sintering Fine Materials, Štroffek Publ., Košice, 1998

[4] Mihok, Ľ., Majerčák, Š.: Hutnícke listy 1982, 1, pp. 7 -11

[5] Nyquist, O.: Jernkontoret Annaler 1962, 146, 2, pp. 81 - 145