

## Ironmaking

## Effects of alumina on sintering performance of hematite iron ores (Review)

L.LU *et al.*

The integrated blast furnace and oxygen steel-making (BF-OSM) route is still a dominant process for worldwide steel production, currently producing more than 60% of the world's total output of crude steel. The counter-current principle on which the blast furnace operates makes it reliant heavily on the quality of its burden to maintain a sufficient level of gas permeability in its upper shaft and of liquid and gas permeability in its lower part. Iron ore sinter, constituting a major proportion of blast furnace burden in most countries, particularly in the Asia-Pacific region, is therefore expected to have a significant impact on blast furnace performance.

The chemical composition of iron ore fines, together with the thermal conditions that sinter blends are subjected to, plays an important role in forming the primary melt during the sintering process and consequently determines the sinter structure and quality. Considerable emphasis has therefore been placed on the chemical composition and consistency of iron ore fines, particularly in terms of alumina content. However, due to the limited reserves and increasing depletion of high-grade iron ore resources, the alumina content of iron ores is expected to increase gradually. While the increase in such constituents is relatively slow over a long period, it has still caused problems for blast furnace operators.

This paper attempts to clarify the role of different types of alumina present in iron ore fines and their effects on melt formation, sinter structure and sinter quality, as well as the sintering process itself. Mechanisms responsible for the deterioration of the low temperature reduction degradation characteristics (RDI) of sinter due to the increasing alumina content are also reviewed. In addition, potential measures to counter the adverse impacts of alumina on sintering performance of hematite iron ore fines are also discussed.

(cf. *ISIJ Int.*, 47 (2007), 349)

## Transformations and Microstructures

## Efforts to save nickel in austenitic stainless steels (Review)

T.OSHIMA *et al.*

The price of nickel is maintaining high level due to the demand continuing to outstrip supply, therefore the stainless steel, which is the largest consumer of nickel, has been maintaining a high-price.

In this paper, the way of nickel saving by more than half and the comparison of properties between the nickel saving stainless steels and Type 304 were reviewed, and the problem caused by the use of the nickel saving stainless steels were discussed.

Nickel saving stainless steels have the following 4 types: martensitic stainless steels, ferritic stainless steels, duplex stainless steels and Cr-Mn-Ni austenitic stainless steels. Nickel saving stainless steels have both superior and inferior points as compared to Type 304, however they have a large possi-

bility of substitution for Type 304. Further expansion of the use of nickel saving stainless steels is expected if the properties required for the stainless steel are reconsidered for proper demands.

(cf. *ISIJ Int.*, 47 (2007), 359)

## Fundamentals of High Temperature Processes

## Silicon deoxidation equilibrium of molten Fe-Mo alloy

H.ONO-NAKAZATO *et al.*

In order to control the silicon deoxidation reaction for steel including molybdenum, it is necessary to take into account the thermodynamic affinity of molybdenum with silicon. For the calculation of the deoxidation equilibria in the alloyed steel including molybdenum, it is necessary to know the interaction parameter of molybdenum for silicon. However, it is difficult to explain the silicon deoxidation of the alloyed steel including molybdenum by previously reported thermodynamic data. Accordingly, the equilibrium for silicon distribution between Fe and Ag phases in Fe-Ag-Si-Mo system and the deoxidation equilibrium of molten Fe-Mo alloy with silicon are investigated at 1873 K. The atomic fraction interaction parameter of Mo for Si,  $\epsilon_{Si}^{Mo}$ , is determined to be  $43(\pm 13)$  from the equilibrium for silicon distribution between Fe and Ag phases in Fe-Ag-Si-Mo system. The experimental results on the deoxidation equilibrium of molten Fe-Mo alloy with silicon reasonably agree with the calculated ones by using  $\epsilon_{Si}^{Mo} = 43(\pm 13)$  derived in the present study. The oxygen contents after the deoxidation treatment by silicon are estimated for 8 kinds of steel. The oxygen content of ferrous alloys including molybdenum can be reasonably estimated using the interaction parameter of Mo for Si derived in the present study.

(cf. *ISIJ Int.*, 47 (2007), 365)Evaporation kinetics of the molten  $PbCl_2$ - $ZnCl_2$  system from 973 to 1073 KC.WANG *et al.*

The clarification of chlorides evaporation behavior from chloride or oxychloride melts is quite important for the treatment and recycling of fly ash generated from incineration processes of municipal solid waste. In the present study, the evaporation rate of the molten  $PbCl_2$ - $ZnCl_2$  binary chloride system was measured at 973, 1023 and 1073 K. The effects of temperature, composition of the melt and the oxygen partial pressure of atmosphere on the evaporation rate of molten chloride were investigated. The  $ZnCl_2$  in chloride melt evaporated preferentially, but the evaporated amount of  $PbCl_2$  was negligibly small. Calculated activation energy of  $ZnCl_2$  evaporation was  $194 \pm 4$  kJ/mol and that evaporation rate was smaller than that estimated from  $ZnCl_2$  activity for the  $PbCl_2$ - $ZnCl_2$  system. Therefore, the evaporation is considered to be controlled by the slower chemical reaction step than the interfacial evaporation reaction. The evaporation rate increased with increasing oxygen partial pressure in the atmosphere, which might be due to the effect of oxychloride formation.

(cf. *ISIJ Int.*, 47 (2007), 370)

## Ironmaking

Reduction kinetics and catastrophic swelling of  $MnO_2$ -doped  $Fe_2O_3$  compacts with CO at 1073-1373 KA.-A.EL-GEASSY *et al.*

Pure  $Fe_2O_3$  and  $Fe_2O_3$  doped with either 2, 4, or 6 mass%  $MnO_2$  annealed at 1473 K for 6 h were isothermally reduced with carbon monoxide at 1073-1373 K. The oxygen weight loss resulted from the reduction at a given temperature was continuously recorded as a function of time. Reflected and scanning electron microscopes were used to characterize the annealed and reduced samples whereas the different phases developed were identified by X-ray phase analysis technique. The external volume of partially and completely reduced samples was measured by displacement method and the volume change ( $\Delta V\%$ ) was calculated. At a given temperature, the influence of  $MnO_2$  mass% on the reduction behaviour and volume change of  $Fe_2O_3$  compacts was investigated. The doping of  $MnO_2$  showed different effects during the reduction of  $Fe_2O_3$  which is temperature dependant. At  $< 1198$  K, the rate of reduction decreased at early stages with the increase in  $MnO_2$  mass% due to the presence of hardly reducible manganese ferrite phase ( $MnFe_2O_4$ ). At final reduction stages the retardation effect was attributed to the formation of dense iron manganese oxide ( $FeO_{0.899}, MnO_{0.101}$ ). At  $\geq 1198$  K, the presence of  $MnO_2$  promoted the reduction of  $Fe_2O_3$  and the catastrophic swelling resulted from the formation of both metallic iron plates and whiskers was observed. Maximum swelling ( $\Delta V\%$ ) was measured at 1198 and at 1248 K for pure  $Fe_2O_3$  and  $MnO_2$ -doped compacts respectively and it increased with the increase in  $MnO_2$  mass% resulting about 405% for 6 mass%  $MnO_2$ -doped samples. The reduction mechanism was predicted from the correlation between the apparent activation energy values, testing of different mathematical formulations derived from gas-solid reaction model and the microscopic examination of partially reduced compacts.

(cf. *ISIJ Int.*, 47 (2007), 377)Kinetic analysis of spherical wüstite reduction transported with  $CH_4$  gasN.TAKEUCHI *et al.*

Rapid in-flight reduction of fine iron ore transported with CO,  $H_2$  and/or  $CH_4$  gas has been studied for direct use of fine iron ore in iron-making process. In this work, the mechanism and the kinetic of the reduction by  $CH_4$  gas were accurately investigated with spherical wüstite fine particles. The spherical wüstite fine particle as fine iron ore was prepared to simplify the reduction rate analysis. Reduction temperature was varied from 1373 to 1573 K. As the result, fractional reduction of spherical wüstite by  $CH_4$  gas reached over 80% at 1573 K within 1 s. From the cross section observation of the particle after reduction, it was found that the periphery of the wüstite particle was metallized by reducing reaction and un-reacted wüstite core remained inside. Therefore, it was indi-