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Research Article

Wetting of Olivine Sand against Steel Alloys

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Abstract

Olivine sand is used in steel plants operating with Electric Arc Furnaces as Eccentric Bottom Tap Hole. The free opening rate is mainly determined by the performance of the tap hole filler sand. A free opening occurs when steel flows freely from the tap hole to ladle once the tap hole is opened. Various parameters such as sintering behavior, particle size distribution, wettability, etc. affect the performance of the sand. One of the important factors affecting the performance of sand is wetting the sand by molten steel. Olivine sand is a type of sand that used in electric arc furnaces. Wetting of Olivine sand against FeO alloys were presented. The wetting characteristics of liquid FeO alloys in a matrix of the Olivine sand at air pressure and temperature of 1650°C were studied by determining the liquid metal-Olivine contact angles. The median wetting angle values from textually equilibrated samples were found 100°. These results suggest that the steel melt forms in isolated pockets at grain corners or on grain boundaries. This will Increase the permeability of sand And the performance of the tap hole filler sand.

Keywords: Electric arc furnace; EBT sand; Olivine; Wetting

Introduction

In an electric steelmaking, there are great concerns about the operational variables that limit production in the continuous casting process. One of these concerns is free opening the tap hole with very good flowability and permeability of sand.

In order to avoid the contact between molten steel and the clouser tap hole used filler sand. Different types of filler sands can be used into tap hole. Among the important factors in the selection of sand are refractoriness, particle-size distribution, flowability and wettability [1].

Olivine sand is one of the most widely used materials. Its Lower free-silica content and strong resistance to metal attack along with the refractory properties caused that Olivine sand to be used in eccentric bottom tap filler [2].

Pore morphology in EBT filling sand equilibrated with steel molten and significantly controls many physical properties such as elasticity, Thermal conductivity and permeability of the EBT sand [3,4].

Immiscible metal liquids play an important role in controlling the dispersal of steel liquid penetration in the Tap Hole. Knowledge of the wetting properties of such melts allows accurate prediction of their topology on the grain scale, which in turn provides insight into the mechanisms for migration of the steel liquid, and whether the final distribution of steel is likely to be interconnected melt network or whether the steel is isolated pockets [5].

In textually equilibrated liquid-solid systems flow ability of liquid is mostly controlled by the melt fraction and the solid-solid (γ_{ss}) and solid-liquid (γ_{sl}) interfacial energies of the phases involved [6]. The geometry of a melt pocket in the solid matrix is determines by the ratio of the interfacial energies. Interfacial energies equilibrated the contact angle between the melt and the confining grains, known as the wetting angle θ [7,8].

$$\frac{\gamma_{ss}}{\gamma_{sl}} = 2\cos\frac{\theta}{2} \tag{1}$$

If the wetting angle θ is less than 60°, called wetting boundary and an interconnected melt network formed and melt can migrate through the solid matrix. If, on the other hand, θ>60°, melt will be formed to in isolated pockets [9,10].

The wetting angle of Olivine in the Presence of iron melts at 1370-1410°C is very greater than the maximum allowable wetting angle for melt connection have large wetting angles [8]. Pure liquid Fe has a high wetting angle (>100°) in silicate matrix [11].

Experimental Section

The run products consist of Olivine sand and Iron sulfide. Olivine sand from the RHI Company was used as a material matrix. Micro particles of Olivine sand produced in an agate mortar and pestle and sieved through screens to achieve near uniform grain size distribution of particles. The size fractions used in the experiments were between 70 and 60 mesh (210 to 250 μm). Reagent grade powders of FeS as a source of FeO was used. Raw materials were mixed together at a weight ratio of 50-50%. And then in order to make the initial adhesion between particles were added 5% polyvinyl alcohol by weight.

A piston cylinder apparatus was used for experiments conducted at pressures of up to 30 tons. Samples are placed in the dryer for one day and then the tube furnace maintained at a temperature of 1650°C. Heating and cooling rates of the furnace were selected 4 and 7°C/min. In order to simulate experimental conditions and working conditions eccentric bottom tap sand was used air atmosphere.

Microstructural characterization was carried out by a scanning electron microscope (Mira3 Tescan, Czech Republic). Chemical analysis was performed simultaneously with SEM, using energy dispersive spectroscopy (EDS). Wetting angle iron liquid against matrix was measured by using SEM images.

In BSE images with clearly visible liquid FeO pocket-Olivine triple junctions the wetting angles were measured with the angle tool

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of AutoCAD software. In this study the number of angles measured in each sample containing Olivine matrix ranges from 150 to 260. Since the two-dimensional section images taken through melt-grain junctions in various orientations a single measurement will give an apparent angle value, which may be an over or underestimation of the true angle measured perpendicular to the Olivine-iron liquid contact. To account for this effect, the average value of the measured angle population in a sample was taken as this has been shown to be a good approximation of the true wetting angle [12].

X-ray diffraction (XRD) analysis (Cu lamp, λ=1.54 Å, 40 KV, 30 mA, Siemens D5000 model) was carried out on the samples. In order to determine the wettability Olivine sand, grains were kept in the tube furnace with temperature 165°C for 1 h.

Result and Discussion

XRD analyse

Figure 1 presents the XRD patterns of as received Olivine sand that crushed an agate mortar and pestle and sieved. As it seems in Figure 1 the solely detected crystalline phases are Olivine and Forsterite.

Anisotropy of Olivine free surface energy

In the isotropic equilibrium theory of partial melts it is supposed that the surface energies of crystal phases are isotropic. For isotropic solids, Surface tension is independent of surface direction. When isolated from other crystalline grains, their equilibrium shapes, derived from minimizing surface free energy, are spheres. For solids with anisotropic crystal structures, surface tensions are functions of the orientations of their respective planes, which are generally expressed by Miller indices [13].

Surface energy on the surface of the crystal grains can be expressed using the theory periodic bond chain (PBC) developed by Hartman and Perdok. Here's surface energy is defined as energy per unit area. An area that is required to divide an infinite crystal into two Half along a specified plane [14-16]. In PBC theory the crystal structure of systematic searches for chains with a period of strong bonds of network. For Forsterite Olivine, where [SiO_4] tetrahedra are treated as crystallizing units, chains are constructed such that only MgO bonds are broken. If at least two connected chains are found in the same plane, the crystal face corresponding to this plane is called an F (flat) face The higher the bond energy within the plane, the lower the surface energy of the individual crystal face, and the more important the crystal face becomes for the crystal habit [17]. t'Hart applied PBC theory to Olivine and calculated surface energies for different bond models ranging from purely covalent to purely ionic. The predicted crystal habit is elongated along the c axis and slightly tabular on (010) [15].

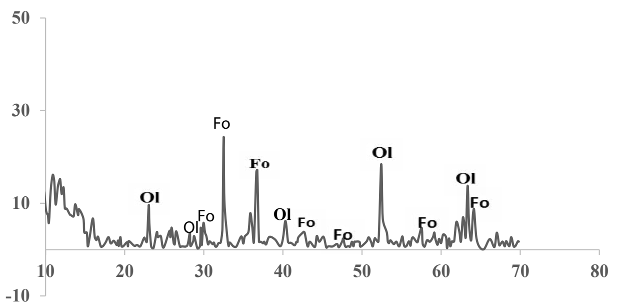

Figure 1: X-ray diffraction patterns for EBT sand.

According to the surface energy values, the stability order of the Olivine faces was found to be (010) < (120) < (001) < (101) < (111) < (021) < (110) [18].

SEM image of Olivine grain Maintained in the tube furnace at 165°C for 1 h is shown in Figure 2. Because of the anisotropy of crystal structure of Olivine, The molten manufactured in all directions will not be able to wetting grains where melt separates the grains labelled I and II, but the same grain boundary of grain III with grain VI is dry.

Measurement of the wetting angle

In the heating process of the sample, oxidation of FeS has occurred. In Figure 3 EDS spectra of isolated region of Fe and O is shown. When FeS is heated in the oxidizing atmosphere, two reactions are done. In the first stage reaction to take place is the transformation of FeS to magnetite or hematite

$$FeS + \frac{2}{3}O_2 = FeS + Fe_3O_4 \tag{2}$$

Or

$$2FeS + \frac{3}{4}O_2 = Fe_2O_3 + S_2 \tag{3}$$

Sponge iron is seen due to gas emission from regions containing iron. Melt pockets in the spongy rim FeO is shown in Figure 3a. The size of the melt pockets is in the range of a few hundred nanometres up to several microns.

By doing these two reactions and produce molten iron working conditions will be similar to work conditions of eccentric bottom tap in electric arc furnace.

The particles were analysed for elemental variations by energy dispersive spectroscopy (EDS) through the use of scanning electron microscopy (SEM).

In SEM image areas included FeO are heavier than Olivine and as a result heavier than FeO region which backscatter more efficiently appear brighter than lighter Olivine region in a backscattered electron image.

The SEM micrographs in Figure 4 illustrate that the distribution of molten. Onions such as S and O have significant effects on the liquid Fe surface tension. Iron sulfide melted at 1109°C and at 1350°C Decomposition reaction is completed and converted to Fe_3O_4. In this case, compared to the previous condition anion to cation ratio of the melt increased. Oxygen-poor melts in which the anion to cation less,

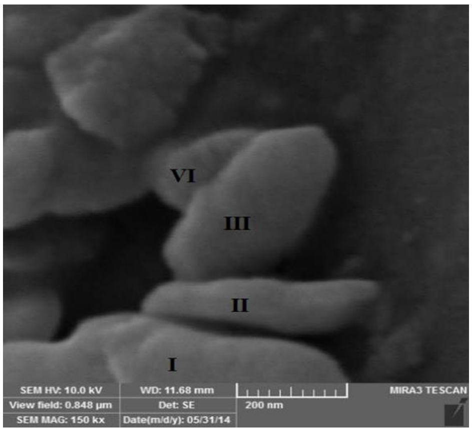

Figure 2: SEM micrograph of Olivine grains sintered at 1650°C.

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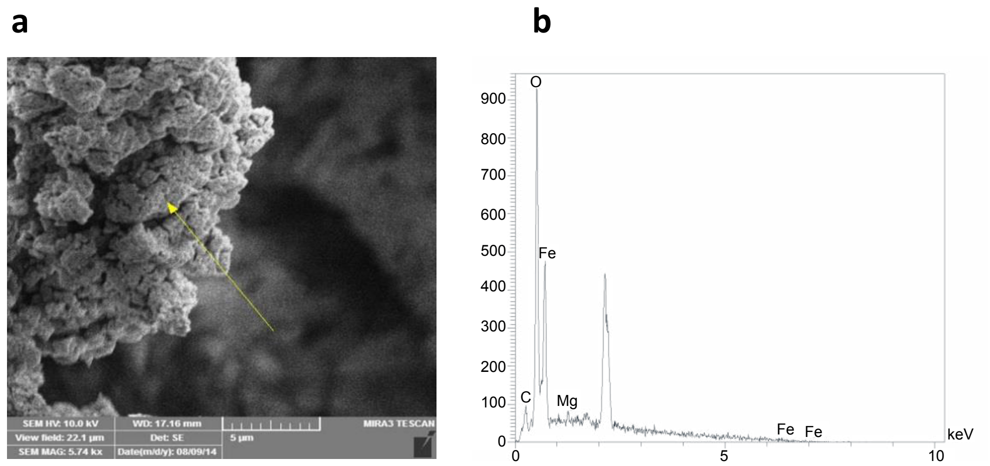

Figure 3: (a) SEM micrograph of isolated iron pockets sintered at 1650°C, (b) EDS spectra of a.

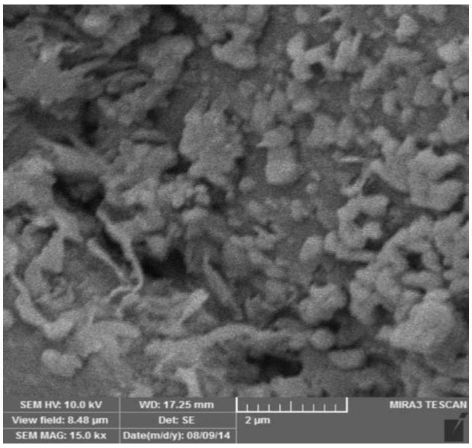

Figure 4: SEM micrograph of Olivine grains with 50% by weight of iron sulfide sintered at 1650°C (brighter phase is iron melt forms in isolated pockets and darker phase is Olivine).

because oxygen-cation bonding is not complete, It has high surface energy. As a result, so do not be perfect wetting of the particles. The increased anion to cation in this way that The surface free energy is dependent on the presence of surface atoms that completely surrounded by arrangements of the periodic structure, therefore the unsaturated bonds are formed.

Unsaturated bonds lead to a reduction in surface energy of the crystal at the interface, As a result of increased wettability. Despite the increase in the ratio of anion to cation, the melt does not have the ability to wetting Olivine matrix. Repeating percentage distribution of FeS-Olivine dihedral angle is shown in Figure 5 and the wetting angle by using SEM micrograph obtained 100°. Thus the irons liquid had not the ability to the wetting Olivine sand and remain isolated.

Conclusion

In this study the wettability of sand by Steel molten was investigated. The wettability angle of sand was obtained at 100°. Leads the molten iron does not have the ability to wetting used Olivine sand in eccentric bottom tap furnace and the liquid permeability in the tap hole reduced. As a result EBT Tap hole Filler in EAF operated steel plants can achieve up to 98% Free Opening without requirement of poking or oxy lancing.

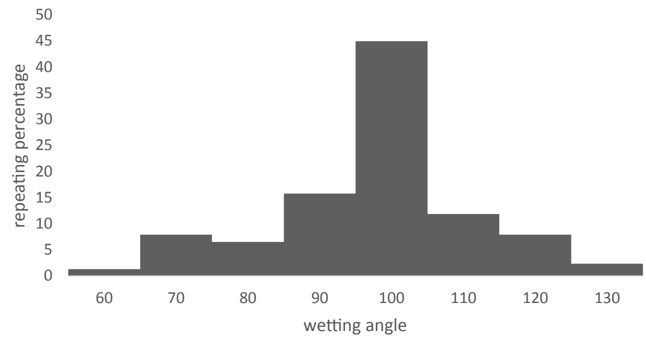

Figure 5: Diagram of repeating percentage distributions for various interfacial angles.

Due to non-wetting of Olivine by Steel liquid has been appropriate selection in steel plants operating with Electric Arc Furnaces as Eccentric Bottom Tap Hole (EBT) Filler during melting operations.

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