

EFFECT OF STATIC AND DYNAMIC EXPERIMENTAL CONDITIONS ON THE DISSOLUTION BEHAVIOUR OF ALUMINA IN BOF SLAGS

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Introduction

The current environmental and economic scenario is expressing the need to include recycling and reuse of residues in all the industries. The recycling and valorisation of Basic Oxygen Furnace (BOF) slag is thus becoming of paramount importance. Hot stage engineering of BOF slag plays a very important role in ensuring its transformation from a low value waste to a high value added product such as a construction material. Materials such as alumina or silica may be used as additives during this hot stage engineering process to modify the composition and mineralogy of the BOF slag. A fast dissolution of the additives ensures a smooth operation of the hot stage slag engineering, and allows sufficient time for these modifiers to react with other components in the slag. For example, they can react with free lime or magnesia and form more stable phases^{1,2}. Hence, the dissolution of these additives in the molten BOF slag must be understood in both thermodynamic and kinetic aspects.

In this study, the dissolution behaviour of alumina particles in molten BOF slag has been studied at various temperatures. The dissolution was carried out under static and dynamic conditions (stirring the molten slag) and it was observed how these conditions effect the dissolution process. It has been found that alumina particles dissolve incongruently in the concerned slag system. The various phases formed during the dissolution process have been identified and their behaviour in the dissolution zone has been observed in detail.

Experimental

Materials preparation

The experiments were performed using industrial high basicity BOF slag (Table 1). The slag was milled and ground to a fine powder to ensure the homogeneity. The Al_2O_3 spheres (>98% purity) were supplied by Sasol.

Table 1: Composition (wt%) of the industrial BOF slag

Slag	CaO	FeO	Fe ₂ O ₃	Al ₂ O ₃	SiO ₂	MgO	MnO	Basicity
Industrial BOF	42-55	14-20	5-10	0-3	9-15	0-5	0-8	3.5-5.0

Experimental setup and methodology

The schematic diagram of the used apparatus is shown in Figure 1. Around 50-70 grams of powdered slag was placed in a molybdenum crucible (inside diameter = 40 mm) and heated in a vertical tube resistance furnace (GERO HTRV, MoSi₂ heating elements). A purified stream of Argon gas (passed through silica gel and a Mg furnace operating at 500°C to remove traces of moisture and oxygen) was blown into the furnace at a flow rate of around 0.3 L/min. After having reached the desired temperature for one hour to ensure the homogeneity of the molten slag, Al₂O₃ spheres (amount of about 5 wt% of the slag) were added to the slag. For some experiments this was followed by stirring with a molybdenum rod for about 30 seconds. The crucible was then taken out of the furnace after the targeted holding time and quenched with water.

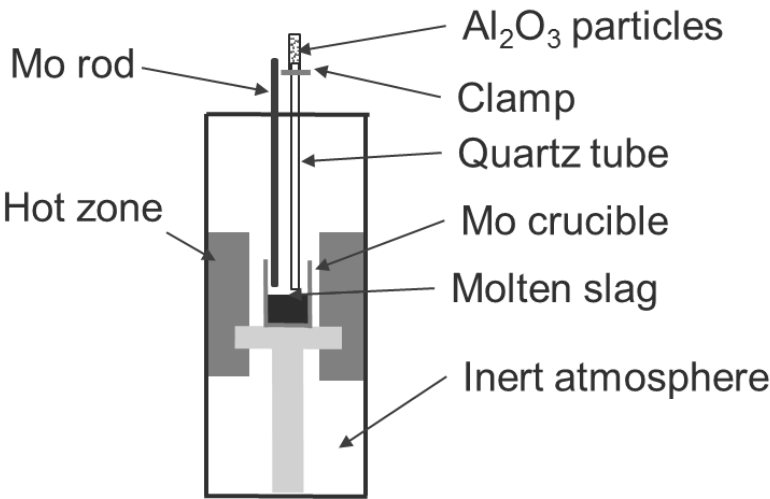


Figure 1: Setup for the addition of particles to molten slag at high temperature

Sample analysis

The quenched slag was drilled out of the crucible, embedded in a resin (Epofix), ground with grinding papers and polished. The polished samples were carbon coated to be used for compositional and microstructural analyses. Compositional analyses were performed with a full quantitative electron probe X-ray microanalysis coupled with Wavelength Dispersive Spectroscopy (EPMA-WDS). The microprobe was operated using an acceleration voltage of 15 kV and a probe current of 15 nA. The quantitative analysis was carried out along a line from the alumina particle to the bulk slag through the interface. For each particle, similar analysis was done at three different locations.

Results and Discussion

Indirect dissolution of Al_2O_3 particles

The composition analysis at the slag/ Al_2O_3 interface indicates that in the current slag system, the dissolution of Al_2O_3 in the molten slag is an indirect dissolution process as Al_2O_3 –CaO reaction products form at the Al_2O_3 /slag interface (Figure 2). These reaction products in turn dissolve in the slag.

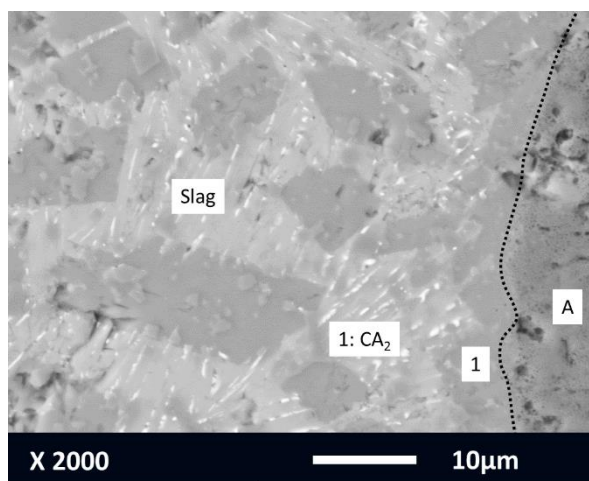


Figure 2: BSE image showing the reaction products formed at the slag/ Al_2O_3 interface. The interface is shown by a dotted black line

The new phase surrounding the partially dissolved Al_2O_3 particle, is found to be CA_2 (CaAl_4O_7) (where C: CaO and A: Al_2O_3). The formation of similar reaction products has been reported by Oishi *et al.*³, who reported the formation of CA_6 and CA_2 when Al_2O_3 is corroded by CAS (S: SiO_2) slags between 1525 and 1600°C.

Effect of stirring on the dissolution process

The concentration Al_2O_3 from the particle towards the slag is shown in Figure 3 for the samples at 1600 and 1500°C. In each case the samples were quenched three minutes after the addition of Al_2O_3 particles. At 1600°C there is a slight increase in the Al_2O_3 content in the slag due to stirring. However, there is no obvious effect of stirring on the formation of reaction products at the Al_2O_3 /slag interface (Figure 3a, 3b). For the samples at 1500°C, the formation of reaction products at the Al_2O_3 /slag interface seems inhibited under stirring (Figure 3c, 3d). The effect of stirring on the samples is found to be dependent on the temperature. The diffusion of Al_2O_3 away from the Al_2O_3 /slag interface in molten slag slows down with decreasing temperature. Stirring has the opposite effect and helps to carry the dissolved Al_2O_3 away from the interface into the slag. As at 1600°C the temperature is sufficiently high for fast dissolution of Al_2O_3 , oversaturation of Al_2O_3 might occur at the interface leading to the formation of reaction products, even with stirring. At lower temperatures, the rate of removal of Al_2O_3 away from the interface due to stirring can be higher than the slower dissolution and hence the formation of reaction products in this case is inhibited.

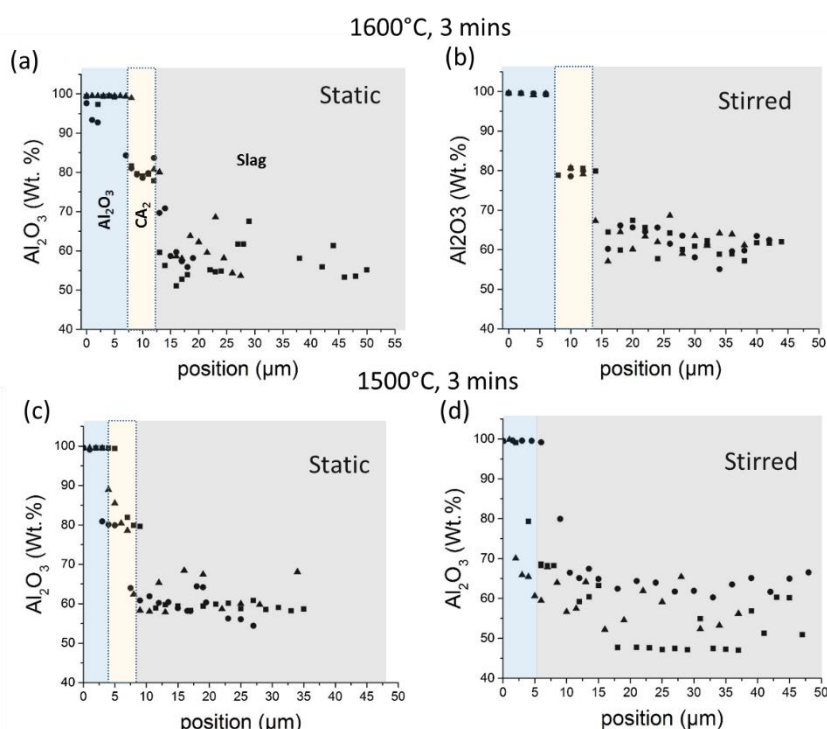


Figure 3: WDS Al_2O_3 weight percentage distribution across the slag/ Al_2O_3 interface

Thus, stirring can influence the dissolution process and might induce a fast and effective dissolution of Al_2O_3 particles in molten slag, especially at lower temperature, where the dissolution rate is slowed down due to negative effect of temperature on the diffusion rate.

Conclusions

The dissolution process of Al_2O_3 particles in molten BOF slag was studied at 1500 and 1600°C. The dissolution of Al_2O_3 particles in molten BOF slag is an indirect dissolution process, wherein CaAl_4O_7 (CA_2) is formed on the surface of the particles *i.e.* at the Al_2O_3 /slag interface. The effect of stirring on the dissolution process was studied. It was observed that the effect of stirring is temperature dependent. It was also observed that stirring can inhibit the formation of reaction products on the Al_2O_3 /slag interface.

References

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