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Fundamental Understanding of Modified Electric Arc Furnace Slag for the Production of Electric Cement

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Electric Arc Furnace (EAF) steelmaking, because of its flexibility, high energy efficiency and low emissions, plays a critical role in decarbonising the steel industry. EAF slag is a CaO-SiO_2-FeO-MgO-Al_2O_3 system, comprising 30~60% CaO, 15~25% SiO_2, 2~10% Al_2O_3, 2~15% MgO, and 10~30% FeO, depending on different raw materials used and varying EAF operating conditions. Majority of EAF slag is used as an alternative to rock fragments in various construction applications. The use of EAF slag to produce supplementary cementitious materials (SCMs) has also been extensively studied by reducing its FeO content through various methods, however, it is still challenging.

To better utilise the EAF slag, a novel technology to directly produce Portland cement clinker in EAF steelmaking (i.e. electric cement) has been explored by adjusting the EAF steelmaking operating conditions. This new technology can produce low-carbon footprint cement clinker, supporting the decarbonisation of the cement industry, another hard-to-abate sector. This paper reports the fundamental understanding of modified EAF slags for producing electric cement through thermodynamic simulation, in-situ observation of high-temperature behaviours, and advanced characterisation of the modified EAF slags.

Understanding the formation conditions and mechanisms of tricalcium silicate (C3S - $3CaO\cdot SiO_2$) phase in EAF slag is the key to enabling its utilisaiton for cement production because C3S is the principal hydration phase in Portland cement clinker. It was found that the C3S content in EAF slag exhibits a notable increase with increasing slag basicity and reaction time. The C3S formation mechanism in EAF slag is different from that in conventional Portland cement clinker production. It depends on the local conditions in the slag. In the lime-rich region it primarily takes place through the direct formation, i.e. $3CaO(s) + SiO_2(l) = 3CaO\cdot SiO_2(s)$, controlled by the diffusion of SiO_4^{4-} in liquid phase, while in the dicalcium silicate (C2S) rich region, C3S formation primarily occurs via the indirect formation: $2CaO\cdot SiO_2(s) + CaO(l) = 3CaO\cdot SiO_2(s)$, with the reaction being controlled by the diffusion of Ca^{2+} in the liquid slag. Cooling regime could play an important role in C3S formation. Rapid cooling from 1600 ℃ to room temperature at a cooling rate of -1500 K/min ℃ led to the formation of a large quantity of dicalcium silicate (C2S) and a calcium ferrite (CF) based slag with a small amount of C3S. Increasing the holding time at high temperatures facilitates the C3S crystal nucleation and growth, thereby increasing the C3S content in modified EAF slag.

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