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Thermodynamics and Kinetic Modelling of Flash Reduction Ironmaking

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Flash reduction ironmaking is being developed as an alternative pathway for producing DRI from iron ore fines. Producing DRI directly from fines eliminates pelletising step. Flash reduction in ironmaking was pioneered by Sohn et al. where they used co-current flow of hydrogen at a temperature between 1200 to 1600℃ with iron ore particle size between 20 to 53 µm. Calix is developing Zero Emission Steel Technology (ZESTY), a flash hydrogen direct reduction ironmaking process where iron ore powder is fed from the top and 100% H2 is introduced from the bottom. The working temperature is between 800 to 1100 ℃ with iron ore particle size < 500 µm. The process employs a vertically oriented reactor with indirect electrical heating, enabling hydrogen to serve solely as a reductant rather than as fuel. The technology has carried out pilot tests with different Australian iron ores and is planning to build a demonstration plant of 30,000-tonne-per-annum in Western Australia. The highest metallisation level of DRI produced from ZESTY pilot test was 98%. Increasing temperature from 900 to 1050℃ and H2/O_reduction ratio from 1.2 to 2 has a positive effect on the level of metallisation. Fayalite (Fe_2SiO_4) formation was observed in DRI produced from goethite/hematite ores. Thermodynamic calculations were undertaken to investigate the formation behaviour of fayalite under ZESTY operating conditions and to assess how ore chemistry and selected additives (e.g. CaO, MgO) influence its stability. These studies support a broader investigation into the role of fayalite in flash hydrogen reduction and its relevance to both metallisation and downstream ironmaking processes. Results showed that adding 10 wt% of CaO to the iron ore reduces the amount of H2 required to reach 100% metallisation level (up to 47%) as CaO can capture SiO2 and preserve FeO for hydrogen reduction. In a separate strategy, calculations predicted that adding 12.5 vol.% CH4 to H2 increased metallisation level from 82% to 97.6%. Kinetic study of ZESTY at 950 °C showed that porosity of the ore and particle size played an important role to the reduction degree of all types of ores. Reduction by 100% H2 was 3 times faster compared to 15% H2. In a separate study of first order kinetic modelling of ZESTY showed that increasing temperature and hydrogen stoichiometric ratio enhanced the level of metallisation. Increasing particle size lowered the metallisation level through decreasing residence time. These findings are consistent with ZESTY pilot plant results.

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