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Thermal and reaction analysis of iron ore agglomerates under hydrogen atmosphere

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Hydrogen ironmaking is considered a promising technology for achieving carbon neutrality in the steelmaking industry. Hydrogen reduction is an endothermic reaction, whereas the conventional CO reduction is exothermic. Therefore, the heat supply to the reaction site is an important issue. Macroscopically, heat is transferred by the hot reducing gas flow, and thermal-fluid analysis is a useful tool for designing the heat-supply process. On the other hand, the reduction reactions of iron oxide take place inside the particles of iron ore agglomerates because the agglomerates are usually porous. The accompanying heat transfer process also proceeds within a particle. Therefore, the simultaneous thermal and reactive behavior of the iron ore agglomerate is quite important as the fundamental information for the thermal design of the hydrogen ironmaking process. In this study, a mathematical model for the thermal and reaction analysis of hydrogen reduction of iron ore agglomerates was developed, and the thermal characteristics were discussed compared to the conventional CO reduction.

The mathematical model consists of the diffusion equation with a reaction term for the gaseous species within the iron ore agglomerate particle, the local reaction rate equations for the iron oxides, and the heat conduction equation. These equations were integrated using the gas concentration and gas temperature adjacent to the particle surface as boundary conditions. Then, the transient distributions of gas composition, solid composition and temperature can be obtained.

Under the CO reduction conditions, the iron oxide reduction proceeds by forming a reaction front, in other words, the reaction occurs within a thin region. Additionally, each reduction step holds its reaction front. Contrarily, the hydrogen reduction shows a broad reaction region, and multiple steps of the reduction reactions take place simultaneously at the same location. The particle temperature is affected by the reducing gas. Under the conditions allowing heat exchange between the particles and the surrounding gas, CO reduction exhibits a behavior in which the particle temperature initially rises due to the exothermic heat of reaction and then drops to the ambient temperature due to heat release to the surrounding gas. In contrast, $H2$ reduction exhibits the particle temperature drops and then recovers by receiving heat from the surroundings. A temperature difference also forms within a particle.

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