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Reaction kinetics and phase transformation during hydrogen reduction of spherical Fe₂O₃ nanopowder agglomerates

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Abstract

The reaction kinetics of spherical Fe₂O₃ nanopowder agglomerates were investigated as a preliminary study to fabricate structure optimized spherical Fe nanopowder agglomerates for processing PM parts. The apparent activation energy E_a for kinetic analysis was determined from nonisothermal thermogravimetric (TG) measurement using isoconversional Kissinger-Akahira-Sunose (KAS) method, and the result is discussed in terms of the phase transformation by XRD analysis and microstructural change by BET analysis. The calculated activation energy was in a reasonable range compared to the reported data for the hydrogen reduction of Fe₂O₃, but it showed three distinct slopes according to the conversion degree of the reaction. The phase analysis revealed that a two-step phase transformation occurred during the reduction process in the sequence of Fe₂O₃, Fe₃O₄, and Fe without an intermediate phase FeO. During the reduction process of Fe₃O₄ to Fe, the reduction rate was retarded by sintering of oxide particles leading to an abrupt increase of activation energy. As the volume fraction of the metallic iron increased through the reduction progress, the reaction accelerated remarkably. This is believed to be attributed to the catalytic role of the reduced Fe particles facilitating reduction of the adjacent oxide particles. These results provide the primary data for understanding the microstructural development of spherical Fe nanopowder agglomerates fabricated by the hydrogen reduction process.

Keywords Fe₂O₃, nanopowder, spherical agglomerate, hydrogen reduction, reaction kinetics

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