Steelmaking with Digital Twin Technology using XDEM (Extended Discrete Element Method)

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Extended Discrete Element Method (XDEM) coupled with Computational fluid dynamics (CFD) is a highly comprehensive and effective tool in simulation of reacting multi-phase flows where the solid particles are suspended in the fluid medium, like in blast furnace. XDEM is a versatile platform for tracking individual particle dynamics along with its thermodynamics state where the particle-particle interactions such as particle collisions, heat/mass transfer, are accurately modelled. On the other hand, the complex fluid interactions and multi-phase fluid flow phenomena are modelled with high accuracy by CFD. The two-way coupling of CFD and XDEM allows comprehensive modelling of fluid phase and particle phase in reacting multiphase flow simulations where the details of each phase are made available at every time step. The coupled CFD-XDEM sophisticated simulations are made more feasible and faster with the use of modern parallel computing architectures and high-performance computing tools. These recent developments have made the CFD-XDEM simulations more possible in obtaining in depth simulations of large-scale multi-phase particle-fluid systems.

The challenge in the complex steelmaking involves intricate multi-physics between particle motion, heat transfer, multiple phases, chemical reactions, etc., that demands high fidelity mathematical models for simulating the complete phenomena is handled by the integrated XDEM-CFD model. In this coupled approach, the gas phase (reducing gases, hot blast, etc.) is modeled as a continuum phase with Eulerian approach. The flow in packed bed of coke and iron ore are simulated alon g side the pressure drop and turbulence. The particles are tracked by Lagrangian approach to capture the motion, chemical state, and heat transfer. The heat exchange between the different particles is modeled by convection, and the radiation effects are considered. The individual particles being tracked in steelmaking process, the drag force, rolling friction, contact forces are computed. The porosity being impacted during the flow and its resistance due to particle shrinkage is modeled. The simulation captures the localized clogging and stagnation in the packed beds. Conduction inside the particles, convection and radiation at the surface are precisely handled. The momentum exchange between the particles and fluid, the mass exchange across the gas-solid interface, and heat exchange are coupled at every time step between XDEM-CFD using different algorithms and libraries.

Keywords: Multi-phase reacting flow, Extended Discrete Element Method, particle-fluid system, computational science.