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Drag force for a burning particle

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ABSTRACT

Fully-resolved simulations of a burning char particle are performed to understand the effects of chemical reastions on the drag force by using the ghost cell immersed boundary method. The momentum, heat and mass transfers at the interface are all considered. Reactive particle with different reaction rates, temperatures and diameters are simulated and compared with a non-reactive adiabatic particle and a particle with an outflow. The results show that both the heterogeneous reactions and the gaseous reactions increase the drag force, which is converse to the effect observed for a non-reactive particle with a pure outflow. This difference indicates that the species and temperature distributions caused by the chemical reactions around the particle play an important role in shaping the drag force. To consider these effects, the Stefan flow Reynolds number and the non-dimensional gaseous reaction rate are introduced to formulate a new drag force correlation for a burning particle based on the fully-resolved simulations. Good performance of the correlation has been demonstrated in the current conditions, and more evaluation might be required for future work.

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The effect of Stefan flow on the drag coefficient of spherical particles in a gas flow

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ABSTRACT

Particle laden flows with reactive particles are common in industrial applications. Chemical reactions inside the particle can generate a Stefan flow that affects heat, mass and momentum transfer between the particle and the bulk flow. This study aims at investigating the effect of Stefan flow on the drag coefficient of a spherical particle immersed in a uniform flow under isothermal conditions. Fully resolved simulations were carried out for particle Reynolds numbers ranging from 0.2 to 14 and Stefan flow Reynolds numbers from (−1) to 3, using the immersed boundary method for treating fluid-solid interactions. Results showed that the drag coefficient decreased with an increase of the outward Stefan flow. The main reason was the change in viscous force by the expansion of the boundary layer surrounding the particle. A simple model was developed based on this physical interpretation. With only one fitting parameter, the performance of the model to describe the simulation data were comparable to previous empirical models.

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The melting characteristics of Vietnamese ilmenite and manganese ores used in chemical looping combustion

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ABSTRACT

For chemical looping combustion (CLC) of solid fuel such as coal, char gasification kinetics is relatively slow and is the rate controlling step, so a high temperature is needed in order to enhance char conversion. However, the maximum allowable temperature in CLC depends on the property of oxygen carrier, and the melting state of the oxygen carrier is the upper limited temperature of the CLC reactors. Therefore, it is necessary to investigate the melting behaviors of oxygen carriers. In this work, a melting test setup with an optical camera-image system was used to experimentally study the melting characteristics of one vietnamese ilmenite and 7 kinds of manganese ores at inert and reducing condition. In inert atmosphere, the prototype temperature and flowing temperature are 1402℃ and 1500℃ for the oxidized ilmenite respectively, while reducing atmosphere can significantly

Cold Model Study of a 1.5 MW_{th} Circulating Turbulent Fluidized Bed Fuel Reactor in Chemical Looping Combustion

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ABSTRACT

A circulating turbulent fluidized bed connected with a riser and an annular carbon stripper (CS) is proposed to be used as a fuel reactor (FR) in chemical looping combustion. The bottom section of the FR is operated under a turbulent fluidization regime, which can achieve enough solid residence time and enhance the mixing of the oxygen carrier with solid fuel. A 1.5 MWth cold model of the FR was designed, constructed, and tested to investigate the hydrodynamics of solid particles with different sizes. Three kinds of quartz sands with different particle sizes (d_{50} = 122, 249, and 392 μm) were used as bed materials to simulate the oxygen carrier. Continuous operation with a reasonable pressure balance was achieved in the cold model. The effects of important variables, including gas velocity, static bed height, and particle size, on the gas–solid hydrodynamics of the FR were measured and discussed. It was found that the transition velocities from bubbling to turbulent fluidization for different particles of d_{50} = 122, 249, and 392 μm were measured to be 0.78, 0.95, and 1.06 m/s, respectively, indicating that the transition velocity increased with increasing the particle size. The solid fraction profile along the reactor height and solid circulation rate were affected by gas velocity and static bed height. A modified correlation was proposed to predict the solid fraction of the annular CS dilute phase, and the predicted results agree well with the experimental data under a wide range of operational conditions.

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Perovskite oxygen carrier with chemical memory under reversible chemical looping conditions with and without SO_2 during reduction

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ABSTRACT

Oxygen carrier materials (OCM) are usually exposed to sulfur-contained gases in the fuel reactor for chemical looping combustion. This work provides both experimental and model work to understand the SO_2 effect on the heterogeneous redox kinetics of a $CaMn_{0.375}Ti_{0.5}Fe_{0.125}O_{3-\delta}$-based perovskite oxygen carrier. The cycle reactivity and redox kinetics under reducing conditions were conducted with and without SO_2 in a micro-fluidized bed thermogravimetric analysis technology (MFB-TGA). The redox kinetic behaviors were simulated by a bubbling fluidized bed reactor model coupled with a two-stage kinetic model. The SO_2 can react with the perovskite to increase the oxygen transfer capacity from 4 wt% to 5 wt%. When the temperature is higher than 1173 K, SO_2 has almost no effect on the H_2 reduction reactivity, while the oxidation reactivity decreases by 50%, but the oxidation is still fast enough to achieve 4 wt% capacity within 8 s. When the temperature is lower than 1173 K, there is a significant sulfur-poisoning effect during oxidation and reduction. The analyses of XRD, SEM-EDS, and in-situ DRIFTS indicated that most of the absorbed sulfur mainly existed in the sulfate/sulfide shell on the particle surface. The chemical kinetics and physical structure of $CaMn_{0.375}Ti_{0.5}Fe_{0.125}O_{3-\delta}$ perovskite can be completely recovered in the absence of SO_2, and this perovskite oxygen carrier is chemically memorable and reversible in its solid structure. The fundamental understanding of the sulfur effect on the redox kinetics and solid structure of the perovskite oxygen carrier provides a new insight to the material development and corresponding reaction mechanisms.

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A framework for evaluating the effect of oxygen carrier characteristics on the performance of industrial-scale CLC using solid fuels

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Abstract

In this work we present a framework to find the potential heat recovery from Chemical Looping Combustion (CLC) using different combinations of oxygen carriers and solid fuels, based on thermodynamic equilibrium calculations. This framework requires thermodynamic information of the reacting species, which is readily available, and no kinetic information for each oxygen carrier, which is scarcer, is required. As the results of this framework are independent of the configuration of the CLC reactor, this tool can aid in the preliminary evaluation of oxygen carriers with potential for CLC applications and relevant operating conditions.

Keywords: Chemical looping combustion; CLC; oxygen carrier; solid fuel

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Demonstration of Chemical Looping Combustion (CLC) with Petcoke Feed for Refining Industry in a 3 MW_{th} Pilot Plant

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Abstract

Chemical Looping Combustion (CLC) is a promising combustion technology with inherent CO_2 capture. This process consists in use of metal oxides, called oxygen carriers, to transfer oxygen from Air Reactor into the Fuel Reactor for combustion of Fuels. Accordingly, Air and Fuel are not mixed and the produced flue gas is concentrated in CO_2 and not diluted with nitrogen. This inherent CO_2 capture results in higher energy and carbon capture efficiencies compared to conventional capture technologies.

This paper presents recent achievements of TOTAL in collaboration with IFPEN on CLC development for the refining and chemical industry with petcoke feedstock. A novel concept has been developed with a two-stage combustion reactor, an integrated solid-solid separator (Carbon Stripper), and non-mechanical solid flow control devices. These technologies have been demonstrated at different scales up to a 1 MW_{th} equivalent cold flow prototype and in a 10 kWth continuous pilot plant. These experimental works permitted to carry out a full-scale process simulation with steam and electricity cogeneration. Different sections of CLC are represented in this simulation including reactor system, flue gas treatment, CO_2 compression, and steam cycle. In addition, the cost of avoided CO_2 has been evaluated for power generation with Chemical Looping technology.

Finally, CHEERS project is introduced in which CLC process will be demonstrate in 3 MWth scale via an international collaboration including nine partners from Europe and China.