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Coal Gasification for Clean Energy Research

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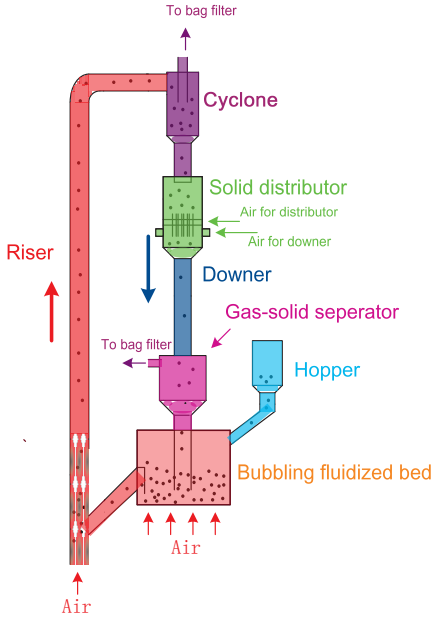
Coal is one of the largest source of energy for the generation of electricity worldwide, approximate 41% of electric power is generated by coal-fired power plants in the world. But the burning of coal is a major contributor to the release of greenhouse gases. Clean coal technology is the new way forward to reduce CO_2 and pollutants emissions. In the recent years, Integrated coal Gasification Combined Cycle (IGCC) and Integrated coal Gasification Fuel-cell Combined cycle (IGFC) have become very popular alternative to the coal fired plants. In particular, the gasifier in this technology can also make use of variable feedstock ranging from low grade coals to biomass such as coconut husk, grass, wood, plant residues with significant amounts of lignin and hemi-cellulose, and cellulose. The syngas from the gasifier can be used to generate multiple products (electricity, hydrogen and chemicals like methanol) and by-products (Sulfur, slag, etc). With the possibility for CO_2 capture and sequestration, an IGCC plant can be developed for a new zero emissions and a high-efficiency process.

A novel triple-bed gasifier

In order to greatly increase thermal efficiency in coal-fired power plants, we have proposed Advanced Integrated coal Gasification Combined Cycles (A-IGCC) and Advanced Integrated coal Gasification Fuel-cell Combined cycle (A-IGCC). In A-IGCC and A-IGFC processes, exhausted heat from a gas turbine and/or Solid Oxide Fuel Cells (SOFCs) is used as heat source instead of partial oxidation of coal for the endothermic reactions in the gasifer. This process recuperates the exergy of the exhausted heat to chemical energy (H_2 and CO) in the gasifier, leading to significant increase in thermal efficiency.

For the exergy recuperation of the exhaust heat in the gasifier, the reaction temperature for steam gasification should be low (700~900 degrees), which is not suitable for fast gasification. In addition, it was found that the volatiles produced such as tar and light hydrocarbon gases including hydrogen strongly interact with char and greatly inhibit char gasification in the gasifier. Thus the volatiles produced should be separated from the remaining char to minimize the inhibition caused by the interaction and maintain the char reactivity in the gasifier.



A novel triple-bed circulating fluidized bed gasifier

A novel high-density Triple-Bed combined Circulating Fluidized-Bed gasifier (TBCFB) is proposed to replace the traditional entrained flow gasifier. The coal is rapidly pyrolyzed in the downer first and the obtained gas and tar are separated from the char using the gas-solids separator. The char then enters the bubbling fluidized to be gasified with steam. The unreacted char enters the riser to be combusted with oxygen. The energy produced from the combustion reaction can be carried by inert sand particles and circulated into the downer and the fluidized bed to provide the heat needed for pyrolysis and gasification reactions.

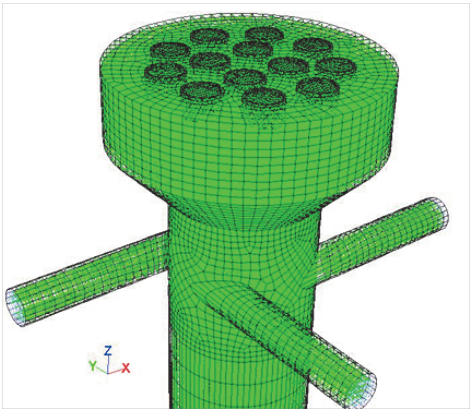
Industry significance

Compared to the conventional oxygen-blown gasification process at high temperatures, steam gasification of coal with high steam to oxygen ratio may reduce the energy for oxygen production in the air separation unit. Steam gasification of coal is also expected to improve the thermal efficiency by recuperation of the thermal and chemical energy contained in the steam produced by the gas turbines.

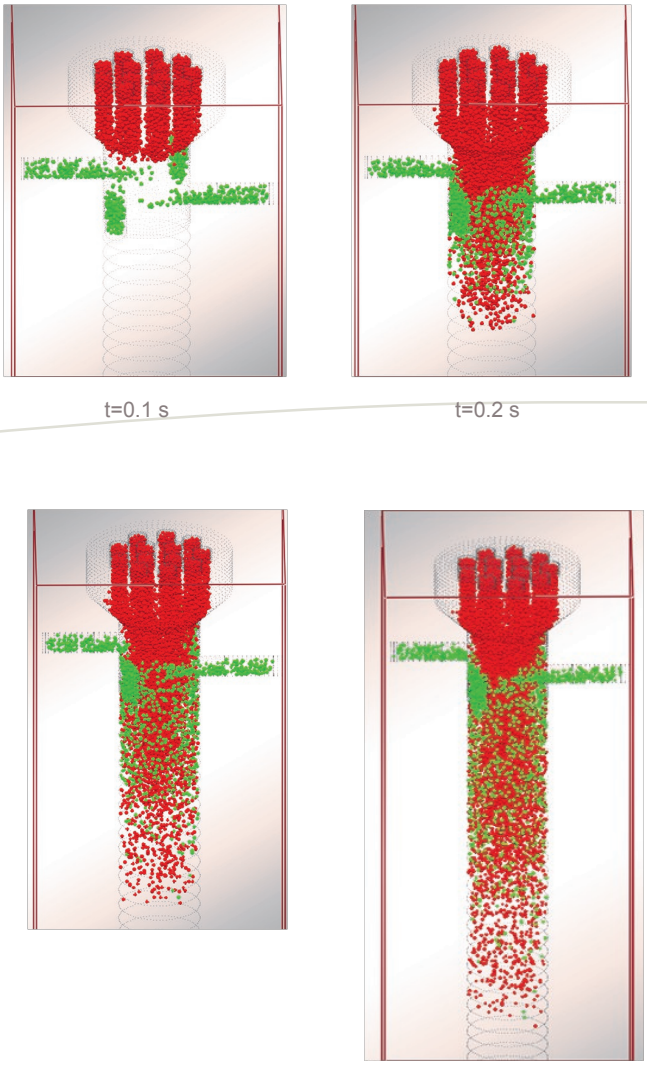
Our Current Research

For the fast pyrolysis of coal, downer reactor is a novel type of reactor due to very short residences and narrow residence time distributions. To achieve high reaction efficiencies in the downer with very short residence times, the behavior of solids within the downer which determined the contacting pattern as well as the extents of mixing between different phases of materials is key to the successful operation of the reactor. The hydrodynamics in the downer especially near the entrance and the development of gas-solids flow are strongly influenced by the type of distributor.

Computer simulations on the gasification of coal are carried out using commercially available software FLUENT and EDEM. Good mixing between the different phases in the gasifier is essential for efficient transfer of heat. Mixing behavior is also influenced by the operating and geometrical parameters in the downer. Thus numerical simulations are also used as a powerful tool to study the flow behaviors before making huge experimental investments. The optimum parameters can be selected, thus increasing the thermal efficiency of the gasifier.



A distributor for the downer gasifier



Mixing between two different particles in downer

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