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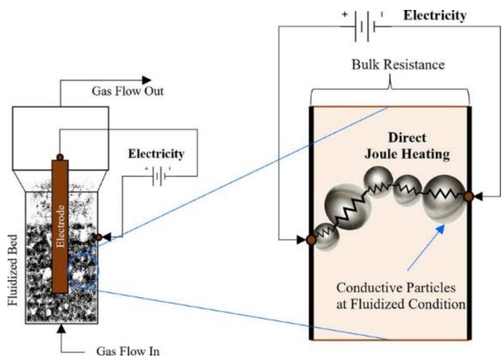
CFD-DEM Study of Hydrodynamics and Heat Transfer in Electrified Gas-Solid Fluidized Beds

Aim

A detailed hydrodynamic and heat transfer study of resistive-heated gas-solid fluidized bed reactors is conducted using computational fluid dynamics (CFD) coupled with the discrete element method (DEM). The research aims to construct a flow regime map to guide the operation of these reactor systems.

Justification

Electrification of the **chemical industry** presents a viable approach to addressing the critical challenge of global warming, driven by the sector's heavy reliance on fossil fuels for energy-intensive processes. As one of the largest contributors to greenhouse gas emissions, the industry must transition to sustainable practices to meet the Paris Agreement's goal of limiting global temperature rise to well below 2°C. Electrification offers a compelling solution by replacing fossil fuel-based heating with renewable electricity [2], significantly reducing the industry's carbon footprint while enhancing energy efficiency and ensuring high-quality production. Among emerging technologies, **electrified gas-solid fluidized bed reactors (eBeds)** stand out as an innovative option, combining the benefits of fluidized beds with selective, efficient electric heating to enable compact, controllable, and decarbonized chemical processes [2, 3].



Schematic of the direct heating of a resistive heated gas-solid fluidized bed [1]

This thesis aims to advance the understanding and development of **resistive-heated eBeds** by leveraging in-house algorithms integrated into the **open-source reactive CFD-DEM framework**, **catchyCFDEM** [4]. The research develops methods for modeling particle chains within the reactor (representing electric circuits), solving the conservation law of electric current density, and coupling electromagnetic (EM) fields with interparticle forces to capture their effect on reactor hydrodynamics. Through detailed simulations of the complex interactions among electromagnetic fields, momentum, and energy balance equations, the study explores the dynamic behavior of eBeds under diverse operating conditions. The findings will be used to construct a flow regime diagram, providing valuable insights into the reactor's performance and guiding the development of efficient and sustainable catalytic processes for the chemical industry.

Program

1. Review fluidized bed technology and CFD studies of electrified reactors.
2. Learn open-source CFD, DEM, and CFD-DEM coupling tools.
3. Conduct validation, parametric studies, and flow regime map development to optimize reactor design and performance.
4. Analyze design limitations and propose improvements based on literature and design handbooks.

References

[1] I. Ahmed, et al., Industrial & Engineering Chemistry Research, 63 (**2024**) 4205-4235.
[2] M. Bonheure, et al., Chemical Engineering Progress, 117 (**2021**) 37-42.
[3] K.M. Van Geem, et al., MRS Bulletin, 46 (**2021**) 1187-1196.
[4] F. Wéry, et al., Chemical Engineering Journal, 498 (**2024**) 155247.

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