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CFD-DEM study of gas-solid hydrodynamics and heat transfer in a pulsed gas-solid vortex reactor

Aim

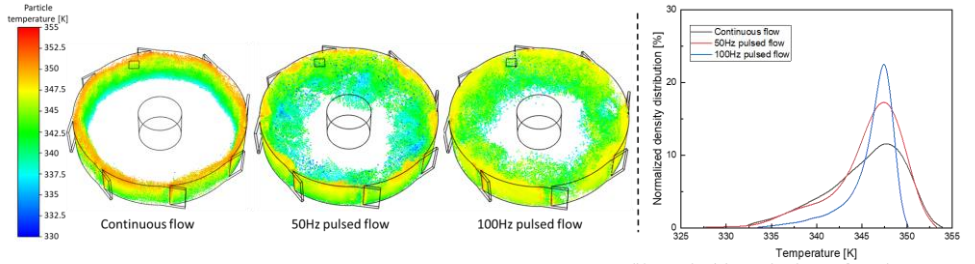
The aim of this thesis is to investigate the gas-solid hydrodynamics and heat transfer in a pulsed gas-solid vortex reactor using Euler-Lagrange CFD-DEM simulation in the commercial software Ansys Fluent.

Justification

The Gas-Solid Vortex Reactor (GSVR) is a promising Process Intensification (PI) reactor technology due to its high heat and mass transfer rates. However, issues such as a high risk of fine powder entrainment, a high carrier gas consumption, and a lack of operational flexibility require attention.

Inspired by dynamic self-organization observed in nature, such as patterns formed on sand by wind, waves, or vibrations, an approach using pulsating rather than constant gas inlet flows can be applied in fluidized beds[1]. This technique aims to control flow patterns within the fluidized bed, applicable for process intensification of particle processing technology. In each pulse, a new array of bubbles forms at consistent locations, providing a predictable and controlled fluidization behaviour[2]. Particles show intense oscillations with the pulsating flow, leading to even higher heat transfer rates[3]. Implementing pulsating flow into the rotating bed of the GSVR is expected to greatly enhance gas-solid contact and heat transfer. Detailed hydrodynamic and heat transfer studies are essential for optimizing the pulsed GSVR.

Using computational fluid dynamics combined with a discrete element model (CFD-DEM) has gained popularity in research on particulate systems due to its ability to provide detailed information on particle scale, such as particle trajectories and forces acting on each particle. With this method, transient data of individual particles, such as their position, velocity, and temperature, can be obtained and analysed. The latter is essential to unravel the hydrodynamic fundamentals and heat transfer behaviour in a pulsed GSVR unit.



(a) Fluidization dynamics and particle temperature distributions in GSVR

(b) Normalized density distribution of particle temperature

Program

- Make a literature study on state-of-the-art CFD-DEM.
- Gain acquaintance with the CFD package ANSYS Fluent and with simulation of rotating particle bed and heat transfer.
- Conduct CFD-DEM simulations, and validate the model using experimental data.
- Process and analyze simulation results.

1. Marc-Olivier Coppens. Annual Review of Chemical and Biomolecular Engineering 12 (2021): 187-215.
2. Laurien A. Vandewalle, et al. Chemical Engineering Journal 430(4) (2022): 133063.
3. Kai Zhang, et al. Powder Technology 367 (2020): 497-505.

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