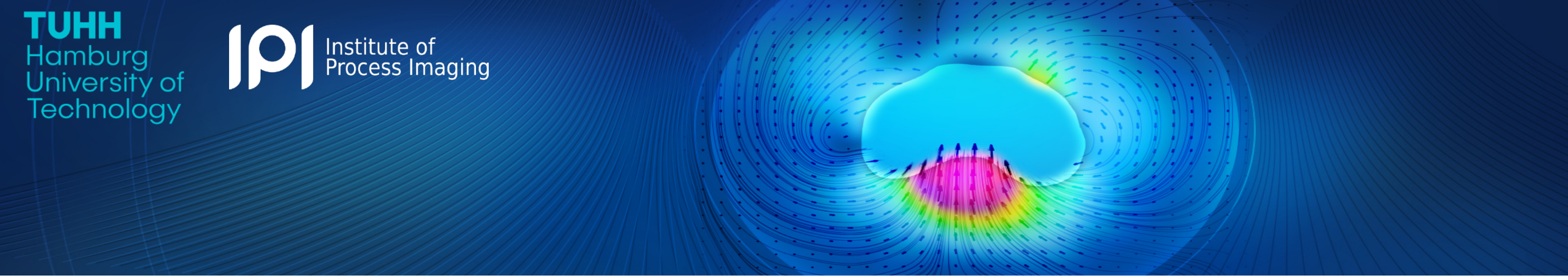

21.05.2025

Project work / Bachelor's thesis / Master's thesis

I3 Junior Project

Investigation of gas-solid fluidized bed hydrodynamics using Magnetic Resonance Imaging (MRI) and Electrical Capacitance Volume Tomography (ECVT)

Introduction: Gas-solid fluidized beds are extensively used in various chemical engineering applications, including tablet coating in pharmaceutical production and powder processing in the food industry, due to their high heat and mass transfer rates. The hydrodynamics such as bubble properties, flow regimes and particle velocities play a significant role in determining the overall bed behavior. These characteristics can be characterized using intrusive probes such as capacitance probes [1] or pressure sensors [2, 3] in three-dimensional (3D) beds, and with high-speed cameras in pseudo two-dimensional systems [3]. However, their drawbacks include altering the dynamics (due to their intrusive nature), providing only localized information, or restricting the range of accessible geometries. Therefore, tomographic techniques, such as Magnetic Resonance Imaging (MRI) [4] and Electrical Capacitance Volume Tomography (ECVT) [5], have emerged as indispensable tools for the non-invasive and spatially resolved analysis of three-dimensional gas-solid fluidized beds. These methods enable the visualization and quantification of the internal dynamics of these systems.The primary objective of the proposed thesis is to validate and compare MRI and ECVT measurements in gas-solid fluidized beds. ECVT is known for its ability to provide high temporal resolution of hydrodynamics; however, it often struggles to sharply define bubble structures and accurately detect smaller bubbles due to its reliance on threshold solids volume fractions and sensor configuration. Conversely, MRI offers higher spatial resolution, enabling better detection of wake structures and bubble dynamics, as illustrated in Figure 1. Nevertheless, MRI involves a trade-off between temporal and spatial resolution, where higher spatial resolution results in lower temporal resolution. By comparing these techniques, the strengths and limitations of each tomographic method in capturing the dynamic behavior of bubbles within gas-solid fluidized beds can be systematically evaluated. This project is in collaboration with the Institute of Solids Process Engineering and Particle Technology. ECVT measurements will be performed by the partner institute.

Tasks:

- Literature review on gas-solid fluidized beds.
- Investigation of bubble properties in 3D beds with MRI for different type of particles.
- Investigation of the impact of humidity on bubble properties.
- Performing image segmentation to determine bubble properties such as spatial bubble size distribution and bubble rise velocity.
- Implementing python scripts to detect bubble coalescence and splitting events.
- Comparison of the MRI data with the results of the ECVT measurements as well as with literature correlations.
- Validation of the measurements using established techniques, such as capacitance and pressure probes, and analysis of pressure signal fluctuations in the time and frequency domains.

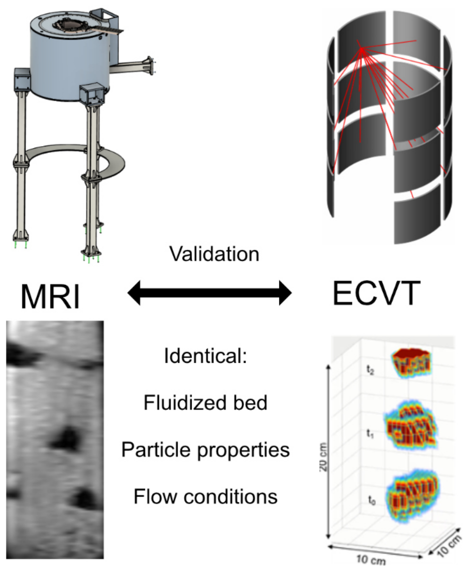

Figure 1: The figure shows, on the left, a 3D model of the MRI system and a frame from intial experiments with poppy seeds fluidization. Black regions indicate bubbles where no signal is detected. On the right, the interaction of ECVT sensor plates at one position is demonstrated, and virtual rising bubbles are detected using the 3D fluxion method [6].

Your profile: Ideally, experimental work experience and programming with Python.

Starting date: June 2025

Contact person: Melis Özdemir, melis.oezdemir@tuhh.de, Tel: +49 40 42878 3124, Building L, Room 3.014

[1] Volker Wiesendorf and Joachim Werther. Capacitance probes for solids volume concentration and velocity measurements in industrial fluidized bed reactors. Powder Technology,110(1-2):143–157, May 2000. [2] J. Ruud Van Ommen, Srdjan Sasic, John Van Der Schaaf, Stefan Gheorghiu, Filip Johnsson, and Marc-Olivier Coppens. Time-series analysis of pressure fluctuations in gas–solid fluidized beds– A review. International Journal of Multiphase Flow, 37(5):403–428, June 2011. [3] Yadong Zhang, Jinbing Zhang, Yuemin Zhao, Xiangyu Zhang, Xuliang Yang, Enhui Zhou, Chenlong Duan, Guanghui Wang, and Liang Dong. Investigations on dynamics of bubble in a 2D vibrated fluidized bed using pressure drop signal and high-speed image analysis. Chemical Engineering Journal, 395:125129, September 2020. [4] Alexander Penn, Takuya Tsuji, David O. Brunner, Christopher M. Boyce, Klaas P. Pruessmann, and Christoph R. M¨uller. Real-time probing of granular dynamics with magnetic resonance. Science Advances, 3(9):e1701879, September 2017. [5] Haigang Wang and Wuqiang Yang. Application of electrical capacitance tomography in circulating fluidised beds– A review. Applied Thermal Engineering, 176:115311, July 2020. [6] Brigham Watson, Lennard Lindmüller, Stefan Heinrich, Jörg Theuerkauf, Yuan Yao, and Yi Fan. Dynamic bubble tracking in fluidized beds via electrical capacitance volume tomography. Chemical Engineering Journal, 487:150461, May 2024.