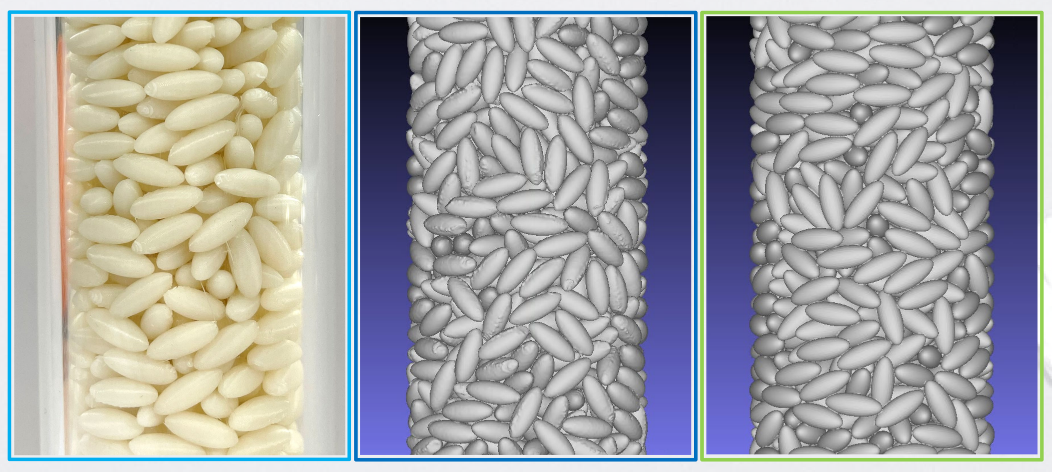
HSLU Hochschule Luzern

Technik & Architektur
Competence Center of Thermal Energy Storage

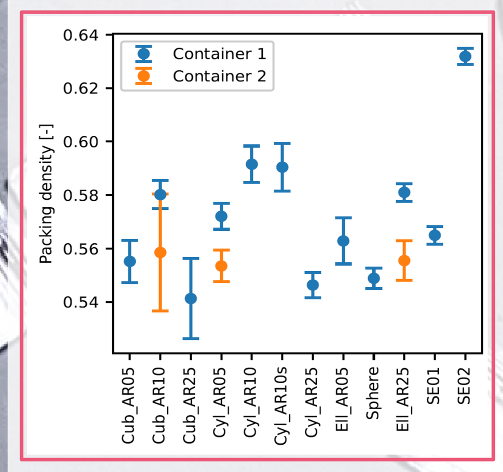
Master thesis MSE Energy & Environment

Shape effects of various geometries on packed bed structures

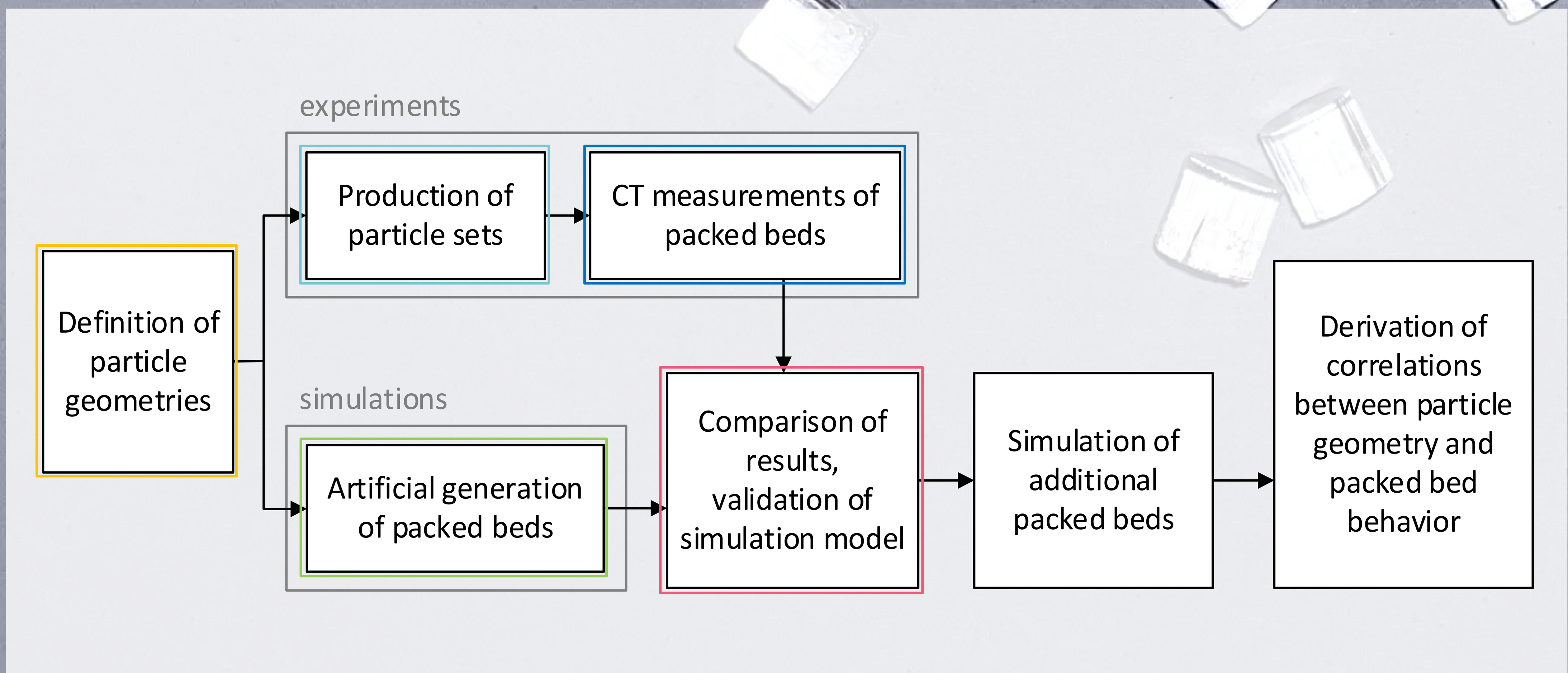
Investigated particle shapes



Experimental (left), CT scanned (middle) and simulated packed beds of ellipsoids with an aspect ratio of 2.5



Packing density of packed beds consisting of different particle shapes



Overview of the workflow

Problem statement

Thermal energy storage (TES) technologies are of great importance to compensate the fluctuating nature of solar energy. Among various TES systems, the principle of latent heat energy storage (LHES) is particularly promising for applications that require high energy density. Solutions with macro-encapsulation (ME) are of specific interest due to their compactness and flexibility.
In an ME-LHES system, capsules filled with phase change material are arranged as a packed bed heat exchanger structure to enhance the heat storage capacity. The interaction between the flowing heat transfer fluid and the packed bed structure has a major influence on the performance of the TES and, thus, the geometry of the capsules plays an important role.
The characteristics of a packed bed, e.g. the packing density, depend on the geometry of the individual particles. This master thesis aimed to identify correlations between a single particle's geometry characteristics, e.g. sphericity, flatness and aspect ratio, and the characteristics of the resulting packed bed.

Solution approach

To identify such correlations, experimental data of packed beds has been generated using computed tomography and simulated data by applying a numerical rigid body dynamics routine. The data was then compared and evaluated to create a solid data set for a regression analysis, based on the dimensionless numbers aspect ratio, sphericity, flatness and relative diameter as predictors and packing density and surface ratio as response variables.

Results

The experimental results showed, that the characteristics of the geometry lead to differently structured arrangements in the packed beds. For example particles with flat faces tend to arrange in packs of similarly oriented particles. Also, the dimensions of the container influence the packing density, due to its wall effects.
The validation of the simulation routine showed that the results of the packing density meet the expected accuracy, whereas the resulting surface ratios are not satisfying.

The regression analysis based on linear and polynomial relations between predictors and response yielded, that the predictor flatness can be omitted due to multicollinearity with sphericity. Further on, additional options should be investigated to depict the non-linear relation between the predictors and the response.

Adina Hochuli

Advisor:
Prof. Dr. Jörg Worlitschek

Expert:
Dr. Gianfranco Guidati

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