Chair of Energy Systems
School of Engineering and Design
Technical University of Munich

Effect of Multiple Storage Cycles on Heat Transfer in Bubbling Fluidized Beds for Thermochemical Energy Storage

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24th FLUIDIZED BED CONVERSION CONFERENCE
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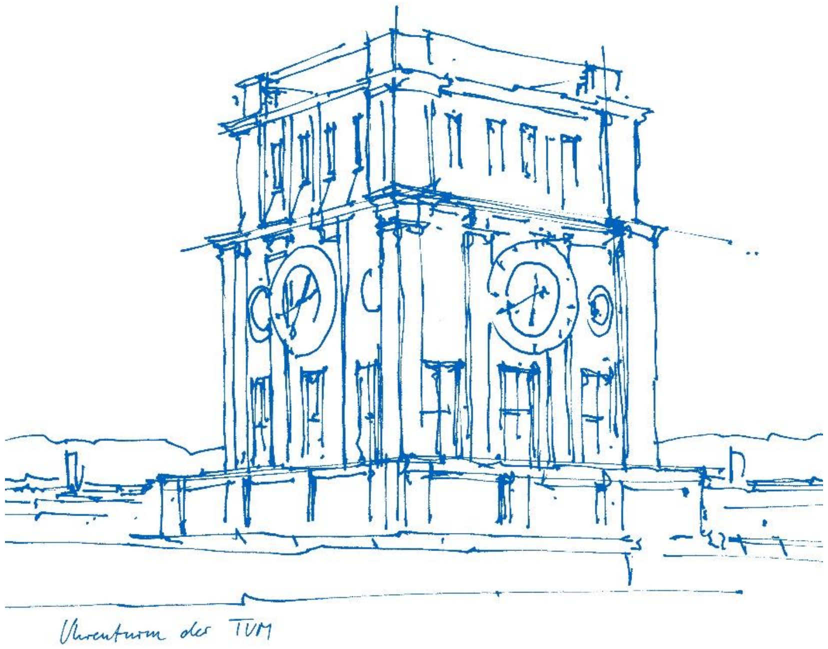


Agenda

- **Introduction:**
  background and motivation
- **Material Recreation:**
  idea, approach and result
- **Heat Transfer Measurement:**
  setup, method and results
- **Conclusions:**
  summary and outlook

Introduction

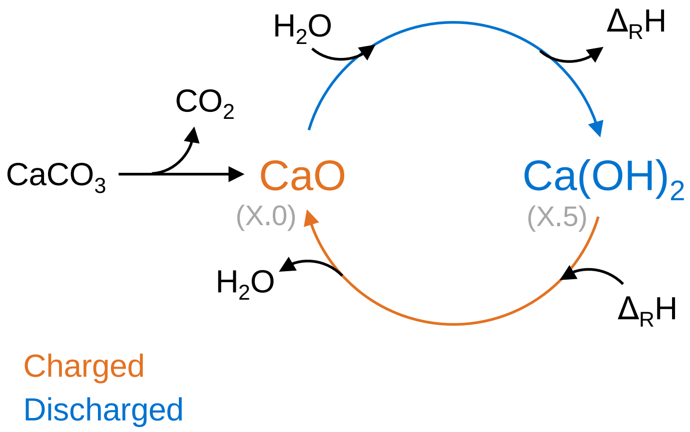
Background and Motivation (I)

Thermochemical energy storage ($CaO/Ca(OH)_2$):

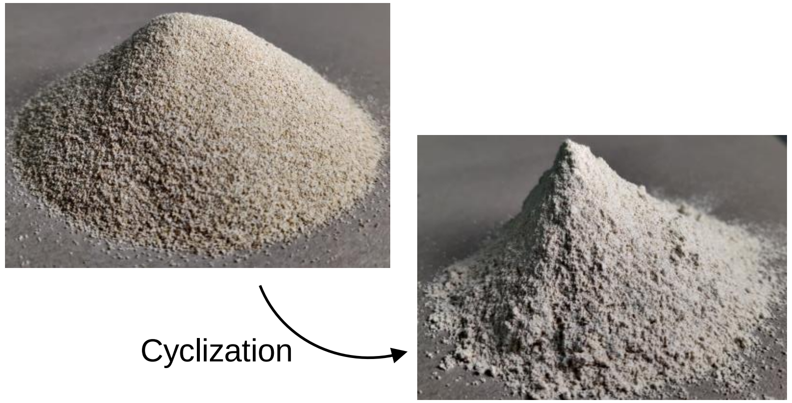
- high energy density in storage material [1]
- reaction temperature at $400 - 600\ °C$
  → ideal for industrial heat and power plant applications
- storage time (theoretically) unlimited
- decoupling of capacity and power possible [2]
- continuous fluidized bed
  → high heat and mass transfer rates
  → simple transport of solids

Challenges:

- during cyclization, particle breakage has been reported [3-5]
  → ultimately Geldart C
- reactor performance influenced by wall-to-bed heat transfer coefficient
  → degradation with increased storage cycles



Principle of thermochemical energy storage with $CaO/Ca(OH)_2$.



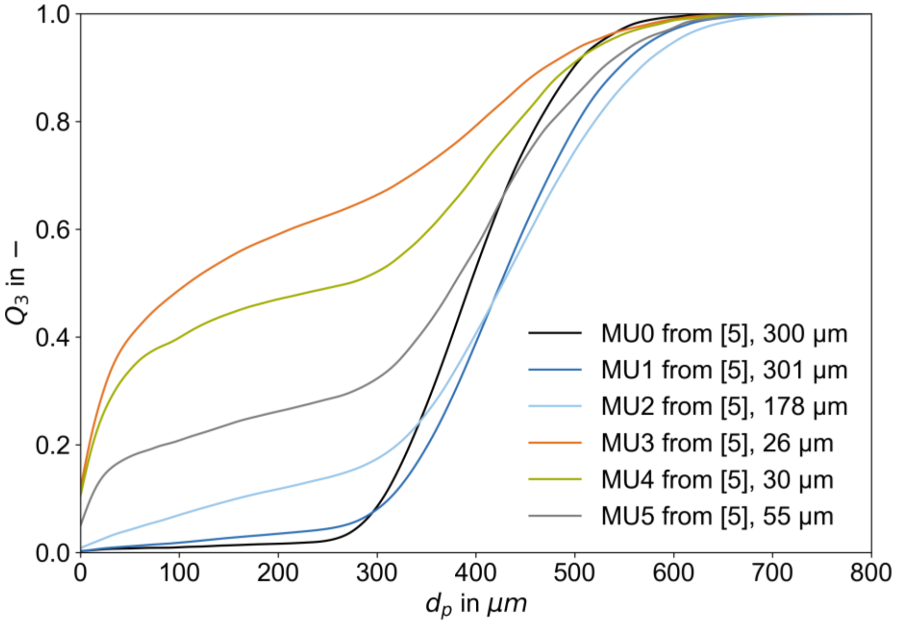
Qualitative representation of particle degradation/breakage.
Pictures for visualization only.

Introduction

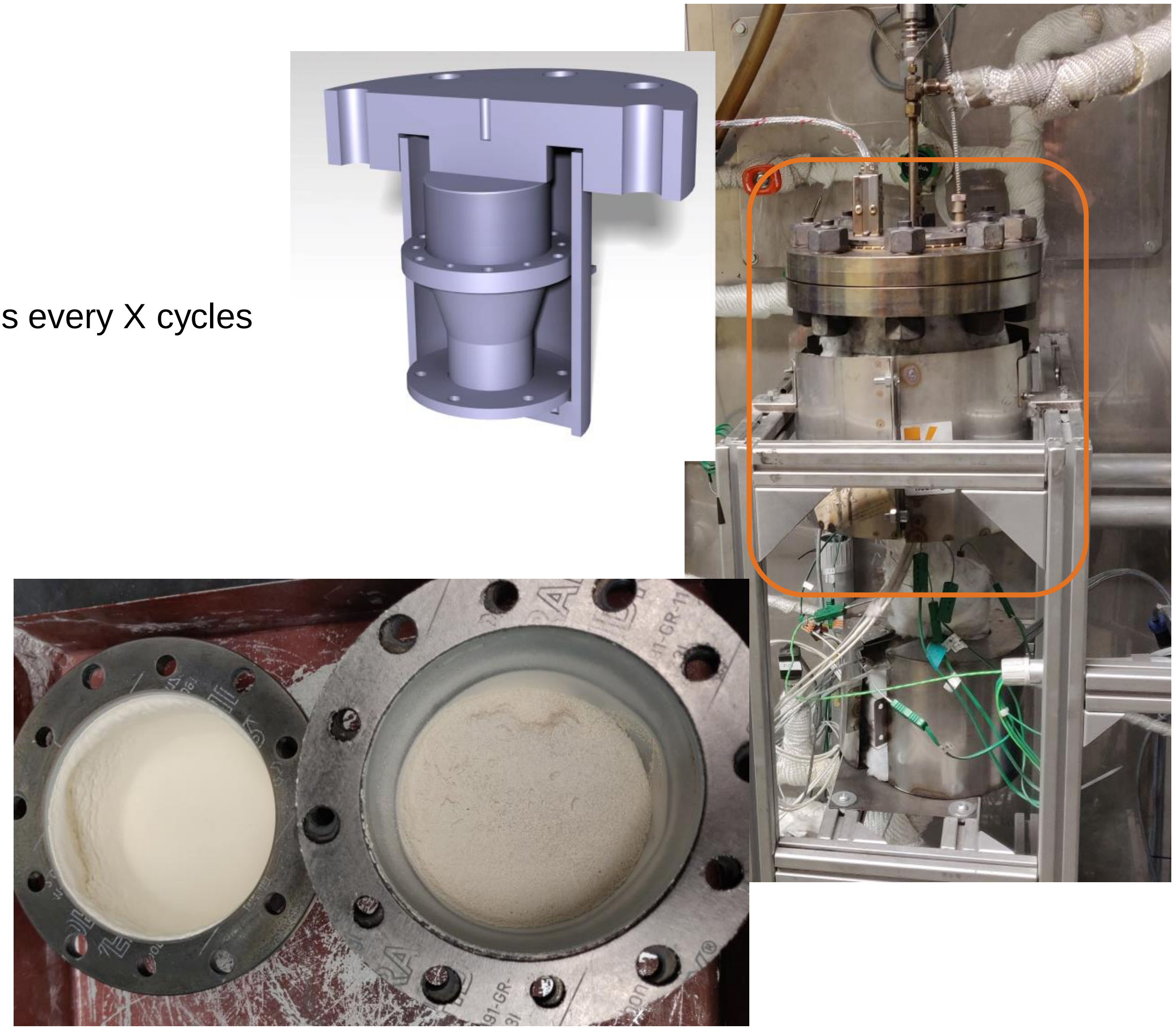
Background and Motivation (II)

Approach [5]:

Mitigate negative effects from particle breakage by replacement of fines every X cycles
→ remove fines from filter, add initial material (make-up)
Initial: 0.5 cycles, make-up after 5.5, 10.5, 20.5, 30.5 and 40.5 cycles



Particle size distributions from make-up experiments [5], SMD given as particle size in legend



Reactor setup from [5], fluidized bed insert: CAD-model, open (left – filter, right – reaction zone)

Material Recreation

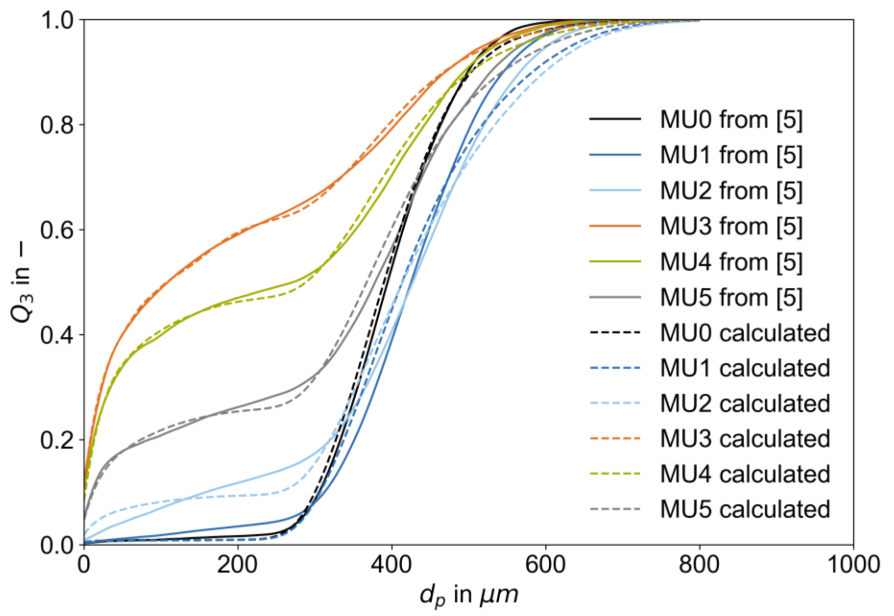
Approach

Goal:

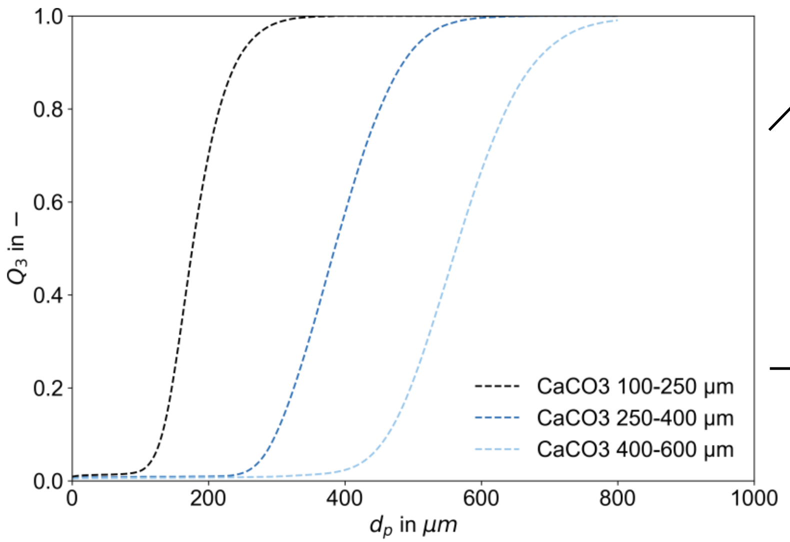
Wall-to-bed heat transfer coefficients for each „made-up“ material (MU**X**)

Approach:

- focus on entire particle size distribution
- $CaCO_3$ as model material
  → mixing process



$$\min_x\left(\left(PSD_{MUX}-\sum_{i=1}^{n} x_i\cdot PSD_i\right)^2\right)\text{ such that }\begin{cases}\sum_{i=1}^{n} x_i=1\\ 0\le x_i\le 1\end{cases}$$



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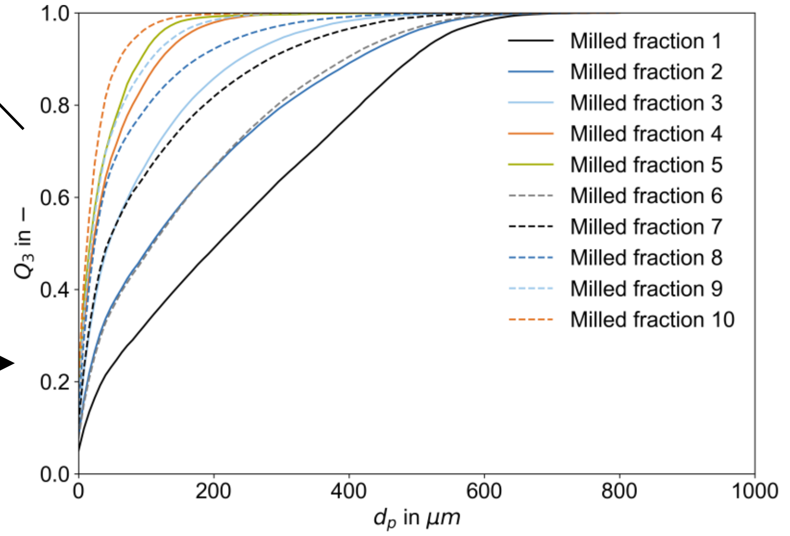
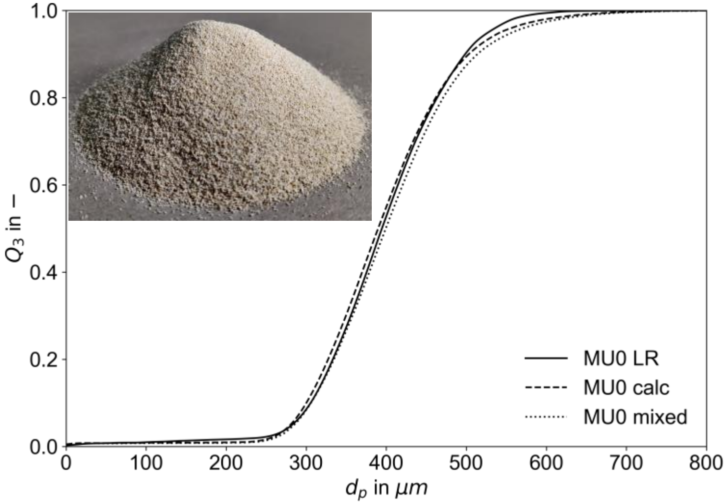
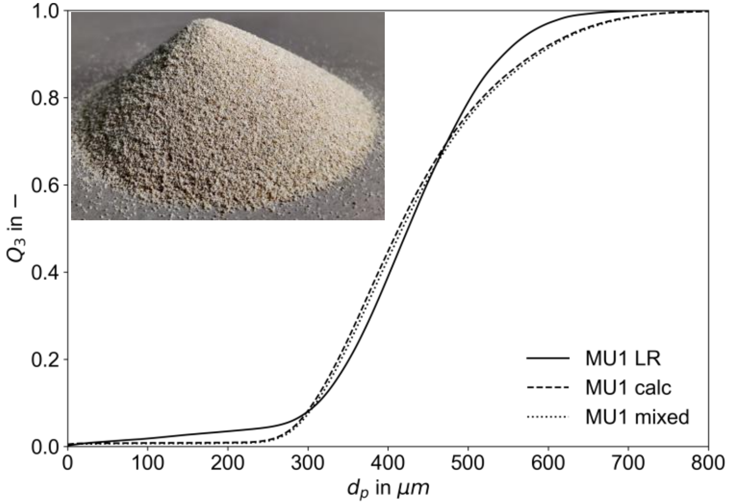
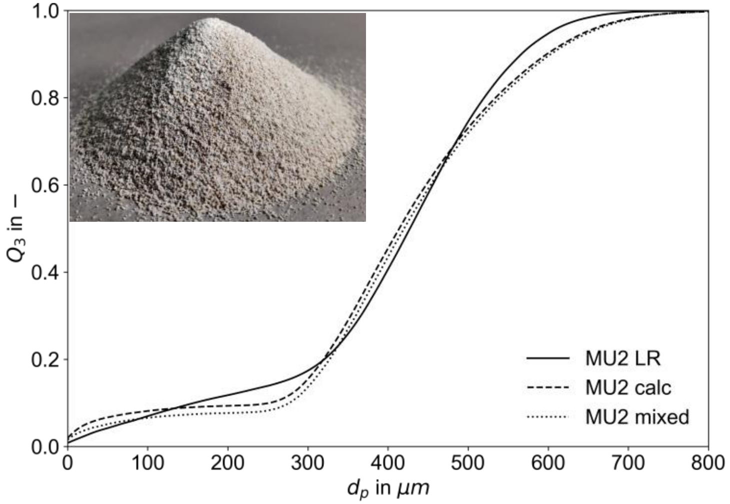


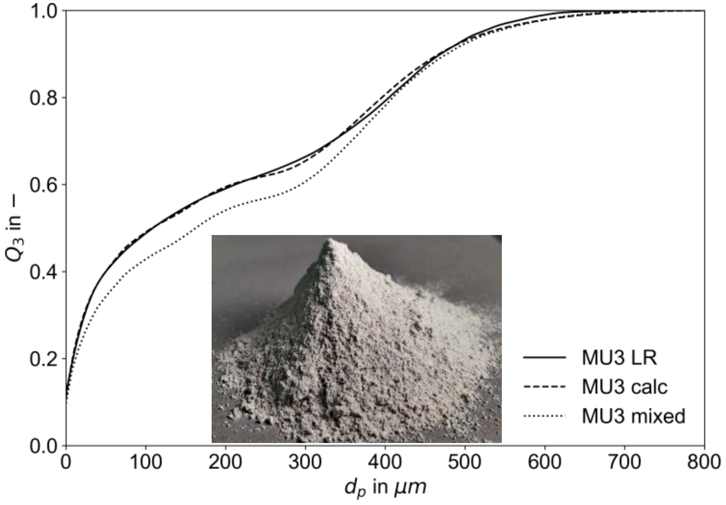
Material Recreation

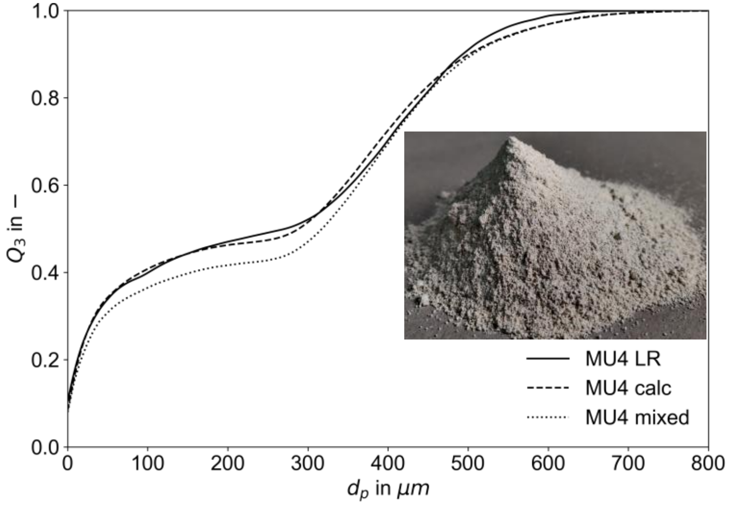
Results

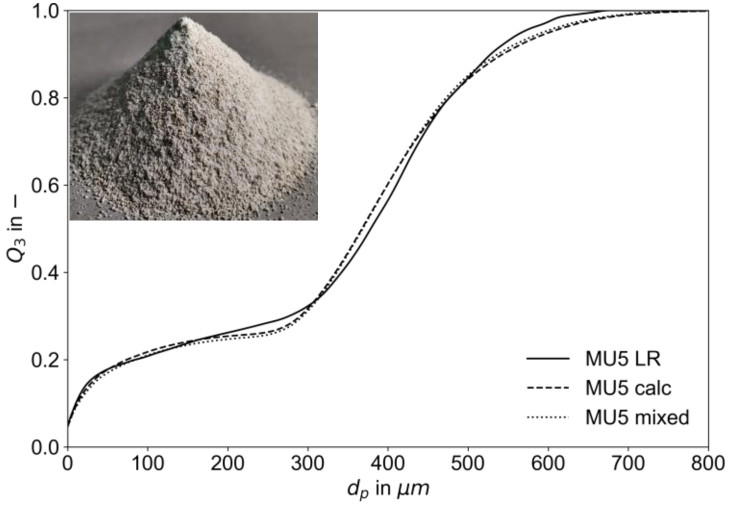












Heat Transfer Measurements

Setup and method

Fluidization test rig:

- glass cylinder – 140 mm inner diameter
- fluidization medium: air
- superficial gas velocity u_0: ≤ 36 cm/s
- temperature: 20-30 °C

Measurement equipment:

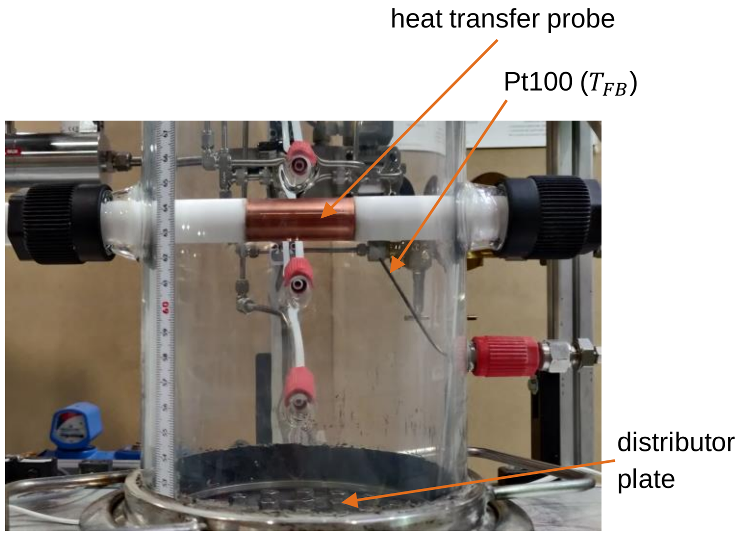
- heat transfer/flux probe (20 mm outer diameter)

$$h = \frac{U \cdot I}{A_{HTP} \cdot (T_{HTP} - T_{FB})}$$

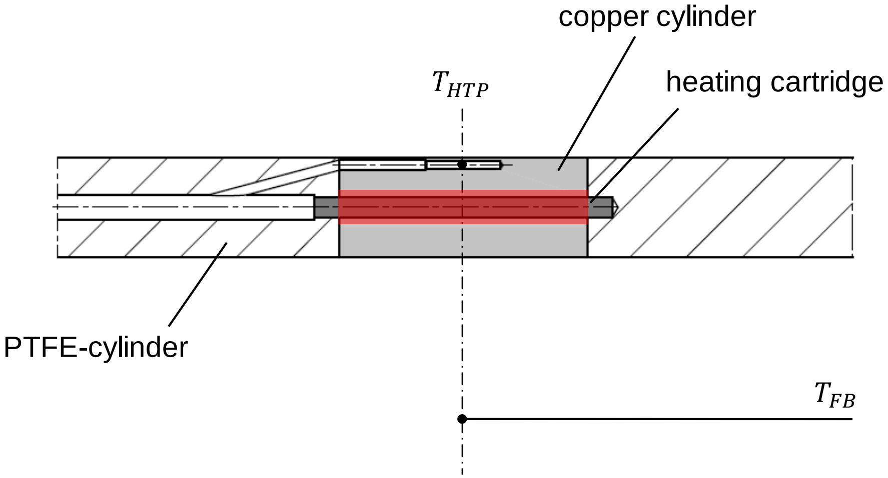
- differential pressure taps

  windbox, fluidized bed (3), freeboard

  → every combination possible



Fluidization test rig with heat transfer probe



Schematic design of an overall-perimeter heat transfer probe (adapted from [6,7])

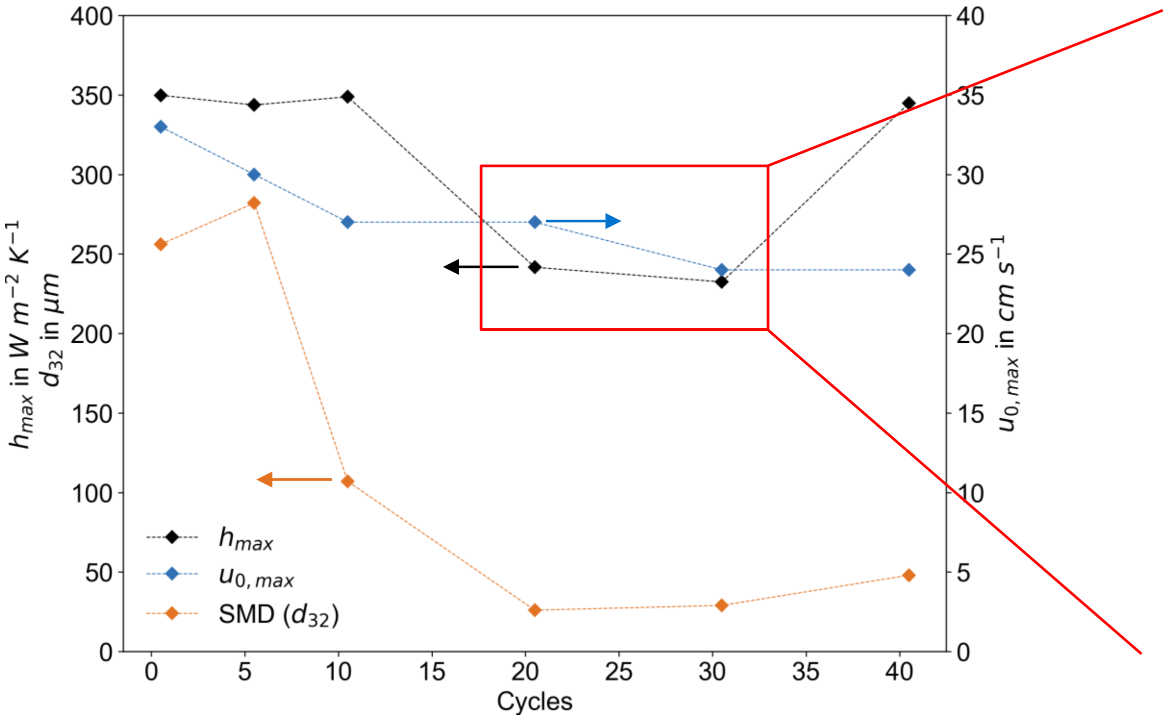
Heat Transfer Measurements

Results (I)

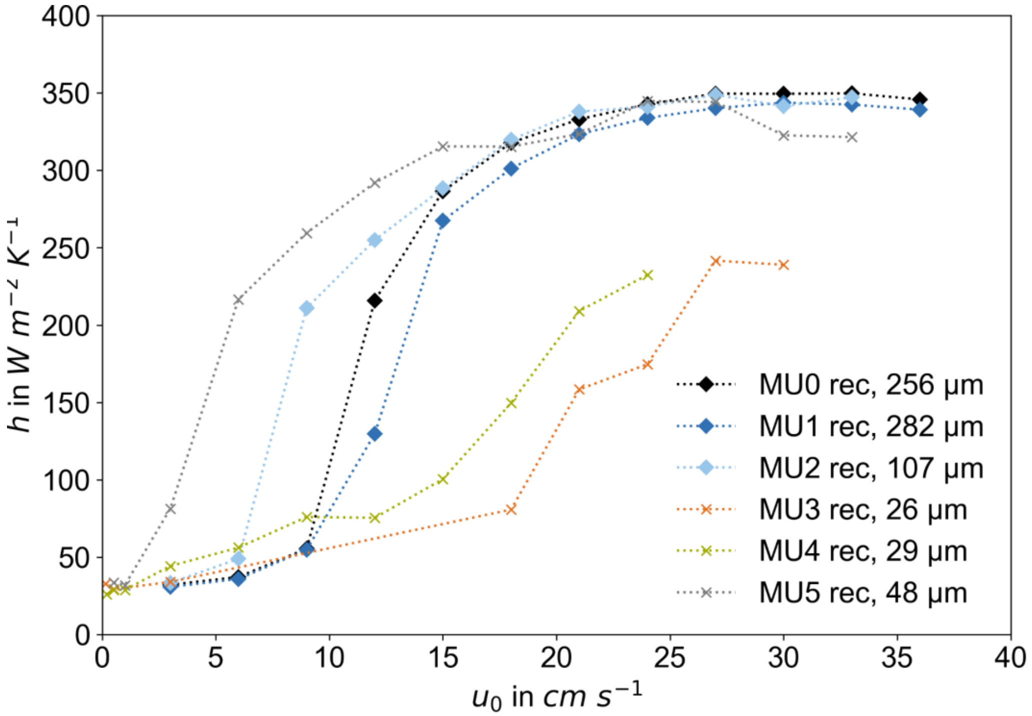
SMD and measure of PSD width

	d_{32} in µm	d_{90}/d_{10} in -
MU0	255,8	1,7
MU1	282,1	1,9
MU2	106,8	2,4
MU3	25,4	59,0
MU4	28,7	53,0
MU5	47,7	26,7

Guideline [8]: $\frac{d_{90}}{d_{10}} < 20$



Measured h_{max}, respective $u_{0,max}$ and SMD vs. cycle equivalent for recreated materials



Measured heat transfer coefficients vs. superficial gas velocity for recreated materials, SMD given as particle size in legend

Summary & Outlook

- **recreation of particle size distributions** obtained from thermochemical energy storage cyclization experiments
  → successful

- **measurement of wall-to-bed heat transfer coefficient** in ambient fluidization test rig with heat flux probe

  → defluidization effects with excessive amount of fines and very broad particle size distributions

  → max. heat transfer coefficient similar for fluidizable particle size distributions

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- **increasing superficial gas velocity** may be beneficial to overcome defluidization effects

- repetition of experiments with **storage materials at elevated temperatures**

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