How to keep light, nonspherical, inhomogeneous active particles in the fluidized bed?

Pal SZENTANNAI and Botond SZÜCS

BME – Budapest University of Technology and Economics
Department of Energy Engineering
http://fbc.energia.bme.hu

How to keep light, nonspherical, inhomogeneous active particles in the fluidized bed?

in other words:

Which effects determine their placing in the fluidized bed?

- ↑ floating to the surface
- ←→ being located in the bed body
- ↓ sinking to the bottom

combustion
gasification
pyrolysis
fast pyrolysis
looping processes

Consequences – in case of FB Combustion

↑ **floating to the surface**

– advantages of the FB technique not utilized

↓ **sinking to the bottom**

– intensive burn at O_2-rich atmosphere ⇨ hot spots
– high NO_X, CO
– danger of agglomeration
– danger of nozzle demages

Consequences

←→ being located in the bed body

– Excellent vertical mixing & heat transfer within the bed ⇨ exact vertical placing within the bed NOT INVESTIGATED in this study

– Over-bed feeding ⇨ satisfactory lateral mixing

– In-bed feeding ⇨ lateral mixing:
excellent research results (Niklasson et al. 2002)
lateral mixing NOT INVESTIGATED in this study

Our focus

↑ floating to the surface

←→ being located in the bed body

↓ sinking to the bottom

Active particles: SRF (partially devolatilized)

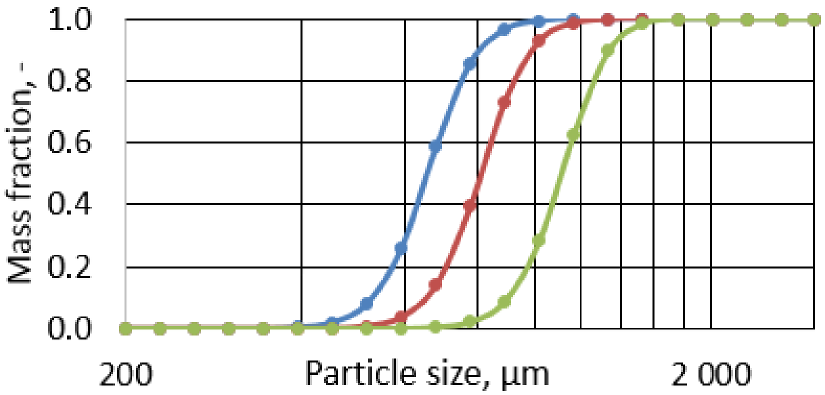
- **light**
- **nonspherical**
- **inhomogeneous**

(mostly relevant also for many sorts of biomass and waste-derived fuels)

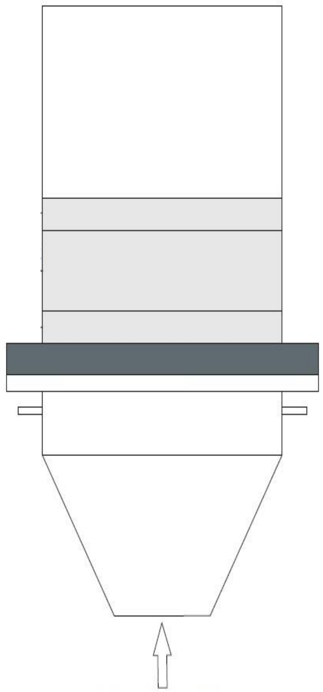
Other inhomogenities minimized

- bed particle size distribution
- same SRF particles backmixed
- temperature (cold model)
- gas flow

u_{mf} = 0.34 0.44 0.64 m/s

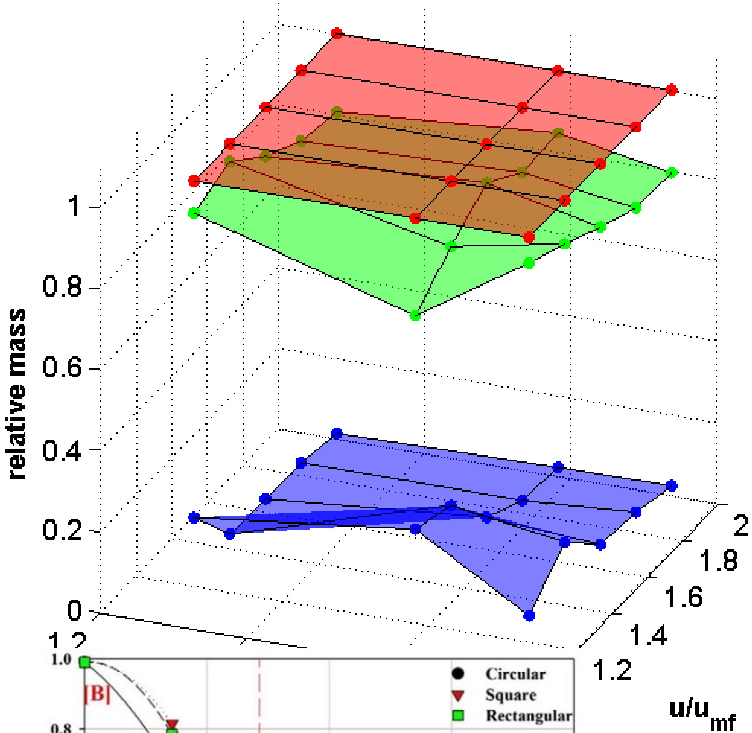


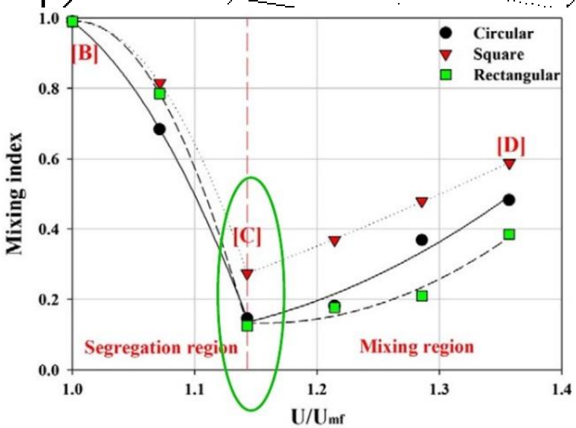
Experimental (bed-frozen method)

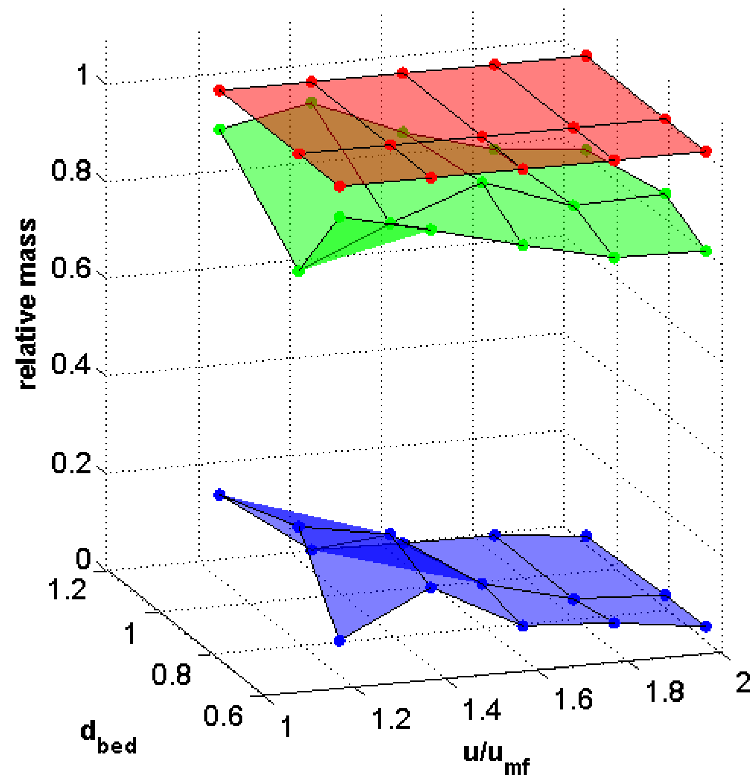


internal Ø	192 mm
top cell	20 mm
middle cell	60 mm
bottom cell	20 mm
No. of orifices	1160 pcs
open area	7.2 %
Δp distr. / Δp bed	> 0.2
active particles	1..2 %wt
mixing time	≥ 20 min

Results – active particle mass fractions







active particle mass fraction found

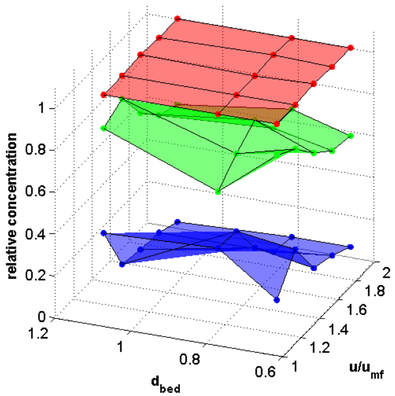
on the top

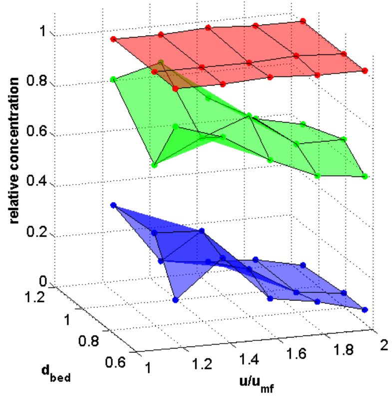
in the bed body

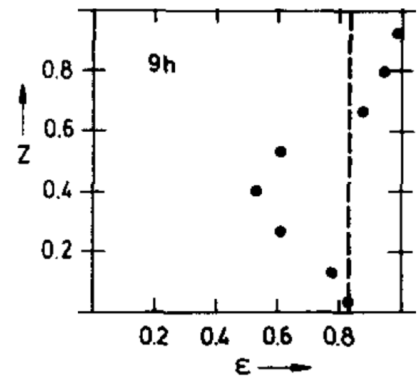
in the bottom

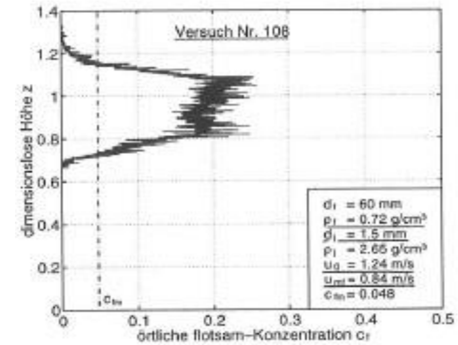
Park and Choi. Powder Techn. 2013

Results – active particle concentrations = mass fractions normalized by volume









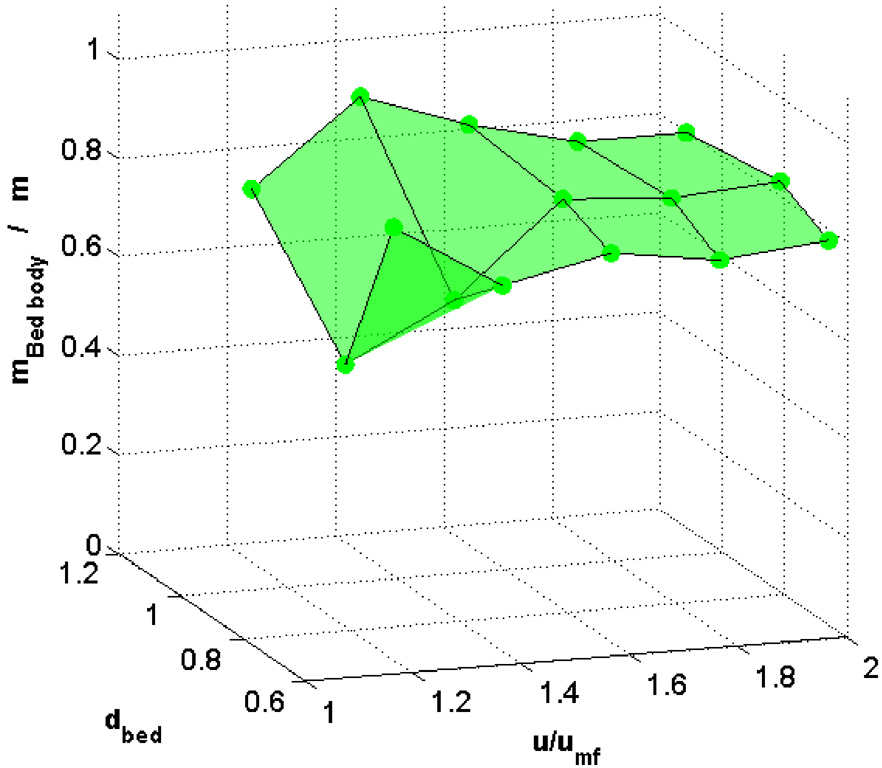
Garcia-Ochoa, 1989 Wirsum, 1996

Uniform active particles!

Mixing index definitions

Kramer's rule	Nienow	Soria-Verdugo	Proposed for practical cases
$\frac{\sigma_0^2-\sigma^2}{\sigma_0^2-\sigma_r^2}$	$\frac{x_{Top}}{\bar{x}}$	$\frac{m_{Upper\ half}}{m}$	$\frac{m_{Bed\ body}}{m}$

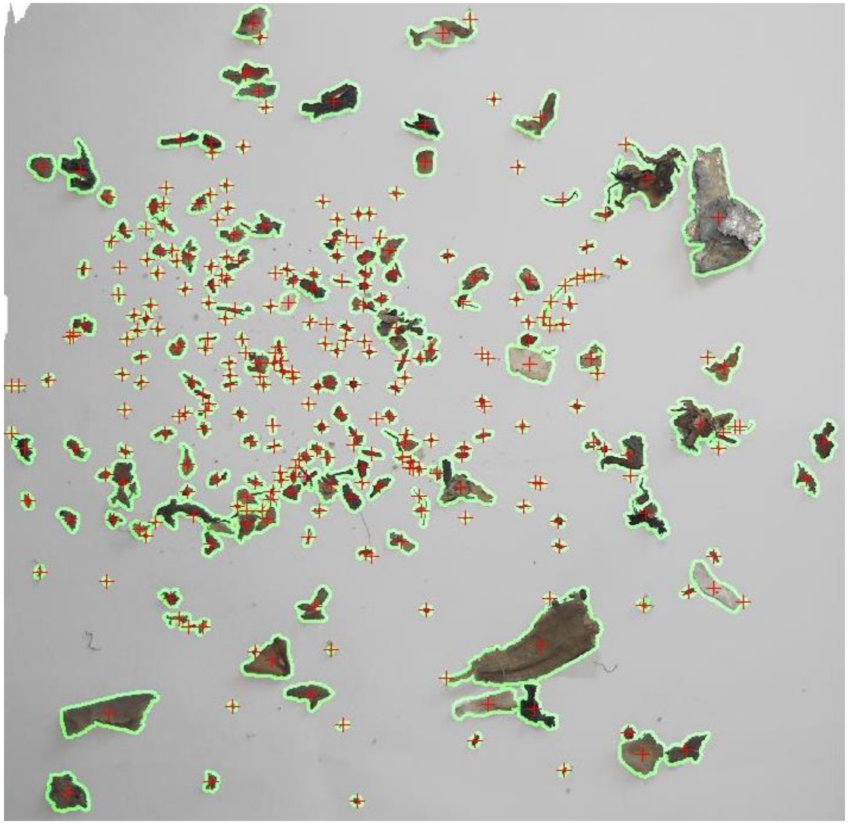
The proposed Mixing Index considers the favourable case of having higher active particle concentration in the bed body



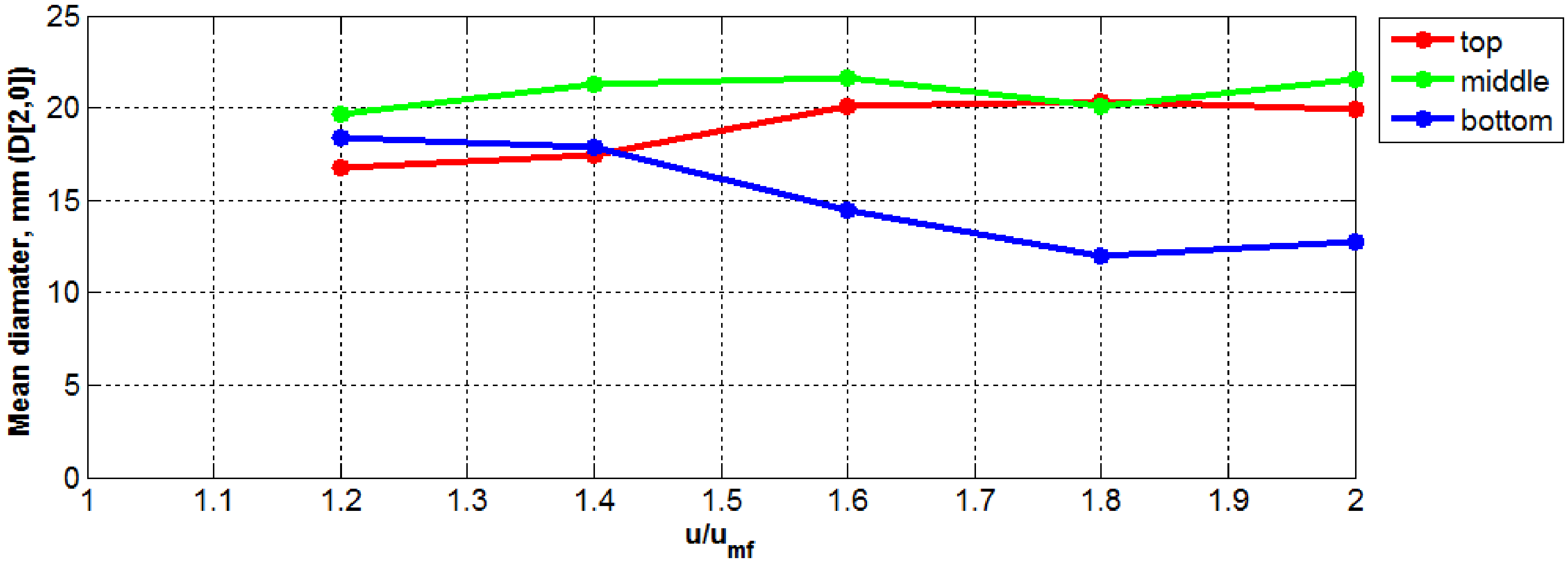
Results – active particle sizes

Remember: <u>nonspherical particles</u> (SRF: flat) ⇨

Image processing methods well applicable



Results – active particle sizes



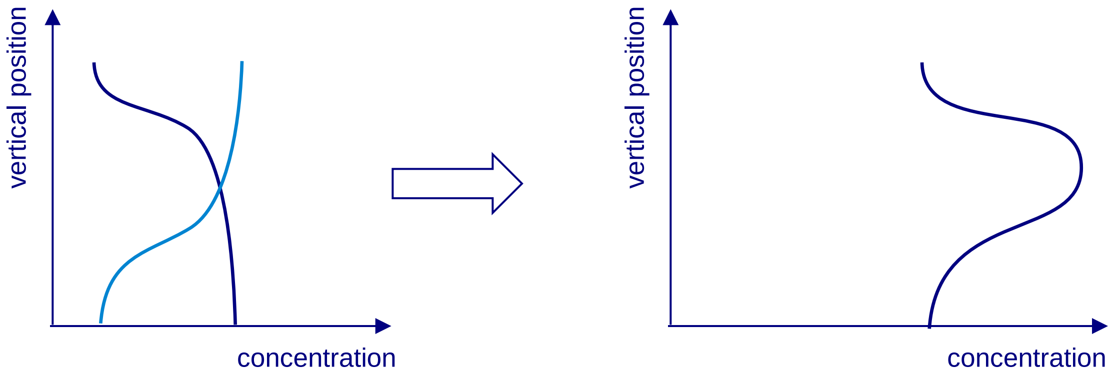
– Biggest particles permanently in the middle!
– Smallest particles in the bottom (in many cases)!
– Systematic shift!

\+ Some particles could be identified → no random locations (systematic positioning with shift)!

Further work – advices welcome!

Mesuring Densities and Heating values

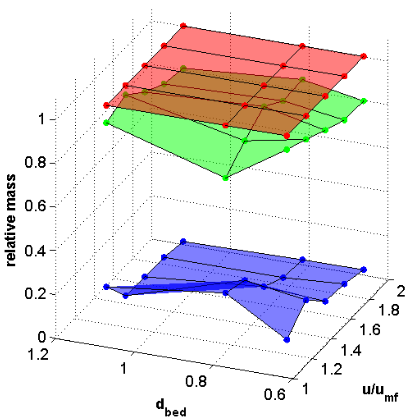
Theoretical / Mathematical / Numerical description based on
– motion equations
– available empirical models for mixing & segregation of binary beds → superposition of several classes within the inhomogenous SRF

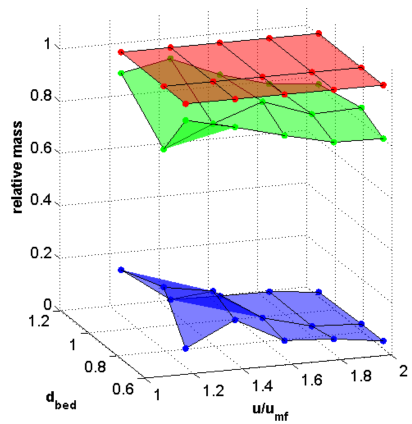


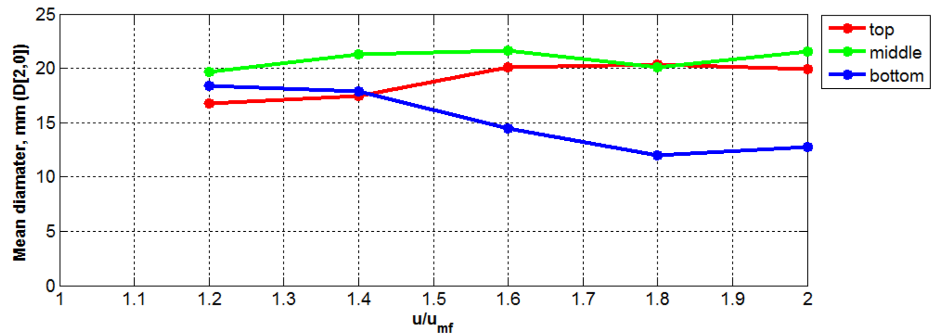
►◄ homogeneous particles → same behaviour (Wirsum, Garcia-Ochoa)

►◄ Why small particles in the bottom?

How to keep light, nonspherical, inhomogeneous active particles in the fluidized bed?







Thank you for your attention!

Pal SZENTANNAI and Botond SZÜCS

szentannai@energia.bme.hu

http://fbc.energia.bme.hu