Heat transfer in Rotating Fluidized Beds in a Static Geometry: A CFD study

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- **THE CONCEPT**
- **THEORETICAL INVESTIGATION**
- **COMPUTATIONAL FLUID DYNAMICS STUDY**
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  - **CONVENTIONAL FLUIDIZED BED**
  - **ROTATING FLUIDIZED BED IN A STATIC GEOMETRY**
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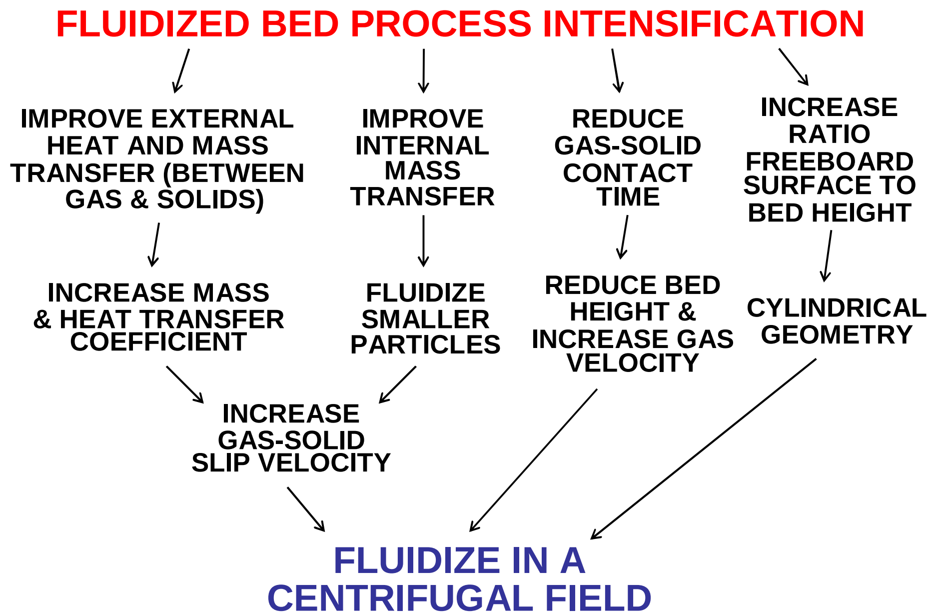
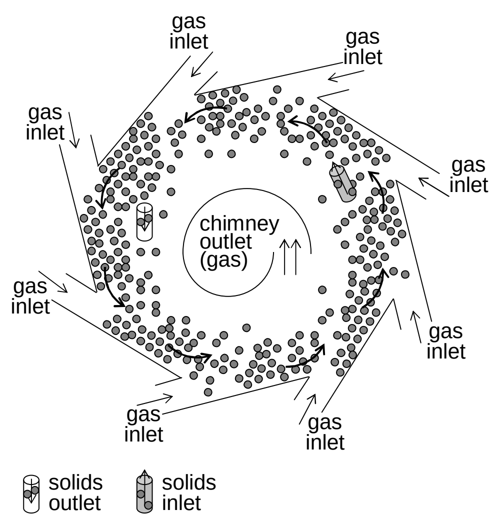
THE CONCEPT



THE CONCEPT



THE CONCEPT

36-cm DIAMETER FLUIDIZATION CHAMBER

1G GELDART D

1G GELDART B

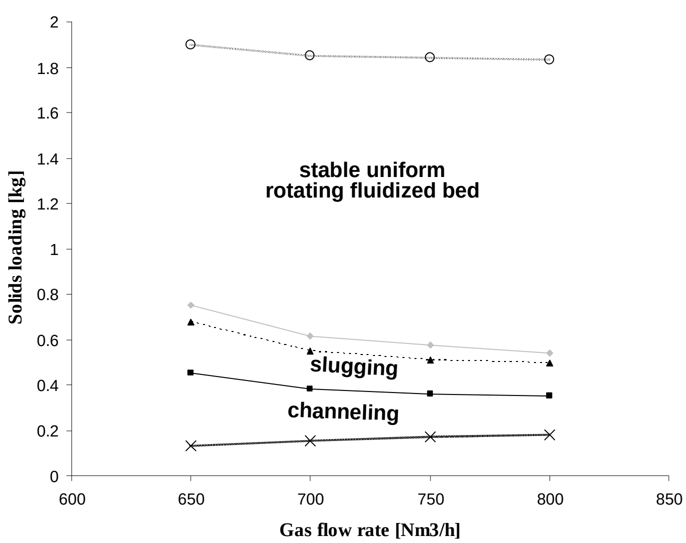
- 1G-GELDART D-TYPE: DENSE AND UNIFORM BED
- 1G-GELDART B-TYPE: SOMEWHAT LESS DENSE AND LESS UNIFORM BUBBLING BED

- HIGH GAS-SOLID SLIP VELOCITIES
- SHORT GAS-SOLID CONTACT TIMES

BUBBLING SUPPRESSED AT HIGHER SOLIDS LOADINGS

THE CONCEPT

CRITERIA FOR STABLE AND UNIFORM OPERATION

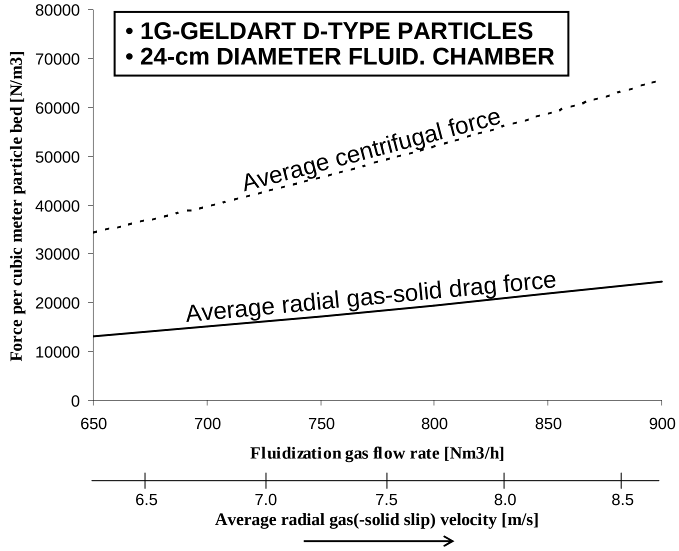


1G Geldart D-type particles,
24-cm diameter fluidization chamber

(De Wilde & de Broqueville, 2007)

THE CONCEPT

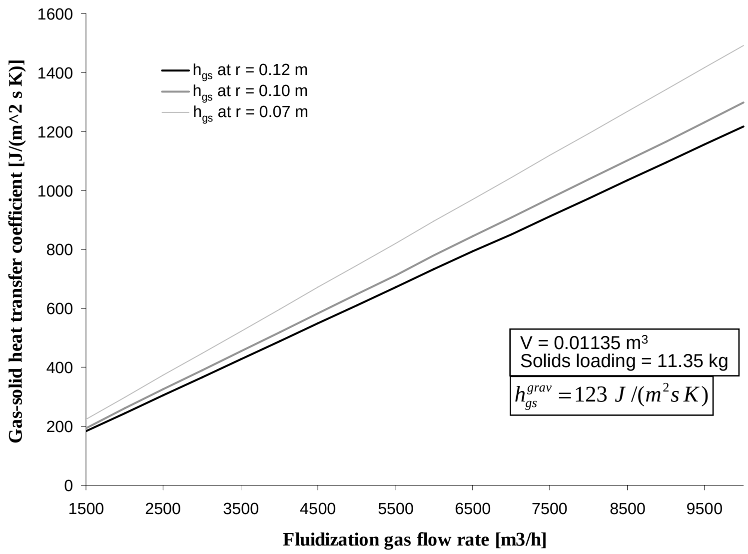
FLEXIBILITY IN THE FLUIDIZATION GAS FLOW RATE



LIMITED RADIAL BED EXPANSION, EVEN RADIAL BED CONTRACTION

GAS-SOLID HEAT TRANSFER COEFFICIENT

THEORETICAL INVESTIGATION



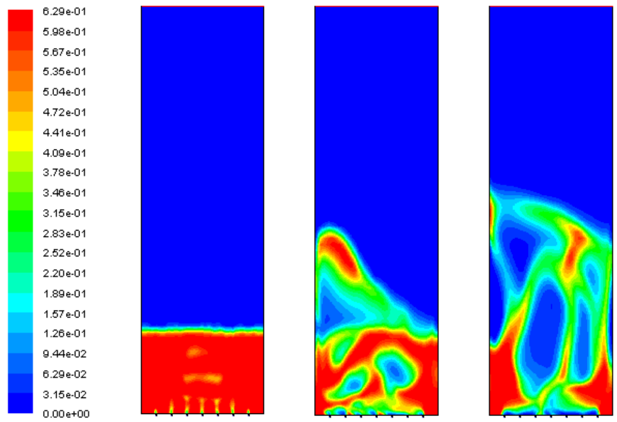
ROTATING FLUIDIZED BED IN A STATIC GEOMETRY POTENTIAL:

- **INCREASED SPECIFIC FLUIDIZATION GAS FLOW RATE (i.e. per unit volume particle bed), due to increased "width"/"height"-ratio**
- **INCREASED FLEXIBILITY IN THE FLUIDIZATION GAS FLOW RATE AND COOLING OR HEATING VIA THE FLUIDIZATION GAS, due to similar effect of the fluidization gas flow rate on centrifugal and gas-solid drag force**
- **INCREASED GAS-SOLID HEAT AND MASS TRANSFER COEFFICIENTS POSSIBLE, due to increased gas-solid slip velocity**

COMPUTATIONAL FLUID DYNAMICS STUDY

- **RESPONSE OF PARTICLE BED TEMPERATURE TO STEP CHANGE IN THE FLUIDIZATION GAS TEMPERATURE FROM *300 K* TO *400 K* AT TIME t_0**
- **Eulerian-Eulerian approach with Kinetic Theory of Granular Flow**
- **Particles: 700 µm, 2500 kg/m^3**
- **Restitution coefficients :**
  - **Particle - particle: 0.95**
  - **Particle - wall: 0.9**
- **Specularity coefficient : 0.5**
- **Solids loading : 33.75 kg/m$_{\text{length fluid. chamber}}$**
- **COMPARISON CONVENTIONAL FLUIDIZED BED AND ROTATING FLUIDIZED BED IN A STATIC GEOMETRY**

CONVENTIONAL FLUIDIZED BED

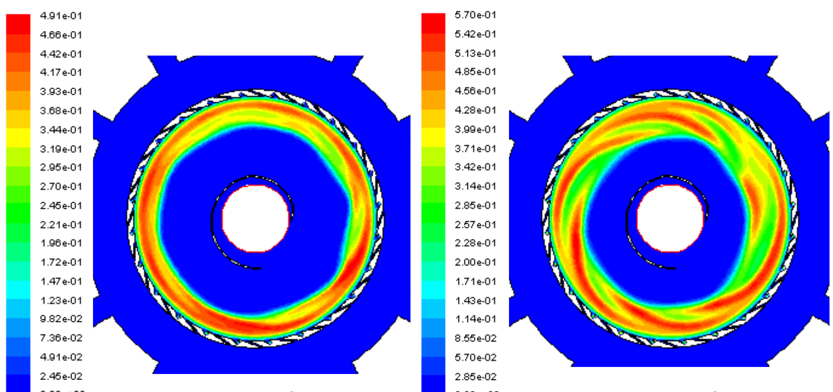


SOLIDS VOLUME FRACTION

195 m^2/h — 540 m^2/h — 1080 m^2/h

FLUIDIZATION GAS FLOW RATE

ROTATING FLUIDIZED BED IN A STATIC GEOMETRY



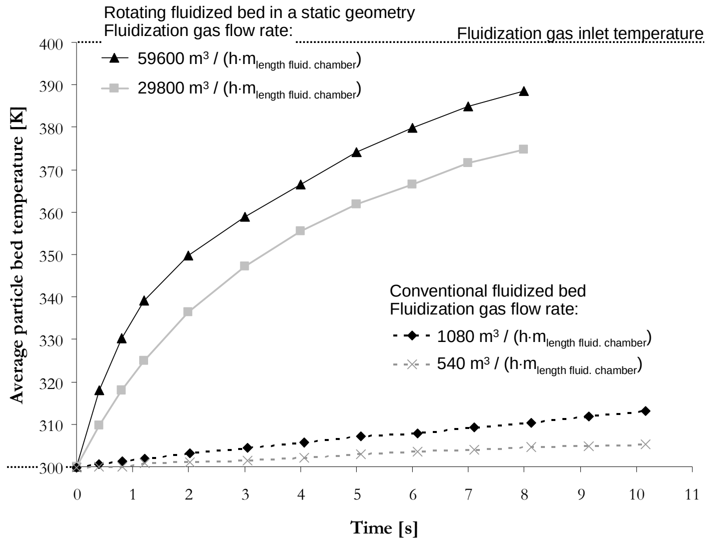
29800 m^2/h — 59600 m^2/h

SOLIDS VOLUME FRACTION

FLUIDIZATION GAS FLOW RATE
(HIGHER THAN WITH CONVENTIONAL FLUIDIZED BED)

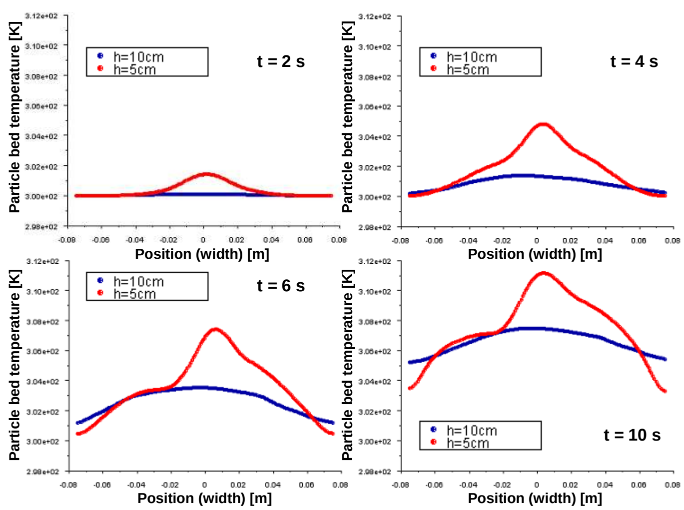
- RADIAL BED EXPANSION LIMITED
- PARTICLE BED UNIFORMITY BETTER THAN WITH CONVENTIONAL FLUIDIZED BED

PARTICLE BED TEMPERATURE RESPONSE



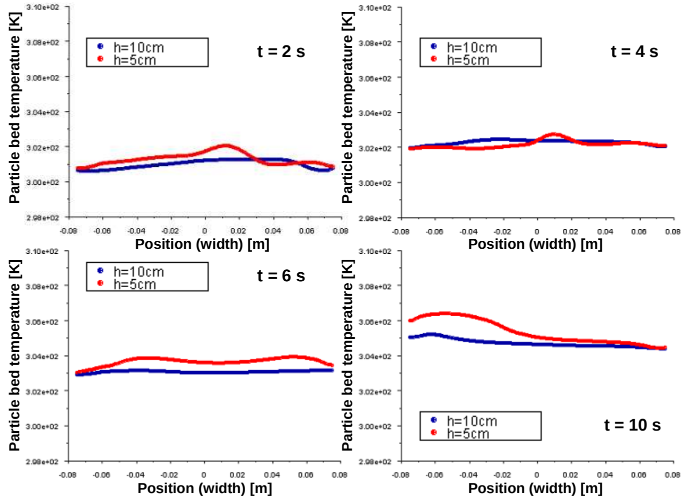
FASTER RESPONSE RFB-SG, DUE TO:
- INCREASED SPECIFIC FLUIDIZATION GAS FLOW RATE
- INCREASED GAS-SOLID HEAT TRANSFER COEFFICIENT

PARTICLE BED TEMPERATURE UNIFORMITY



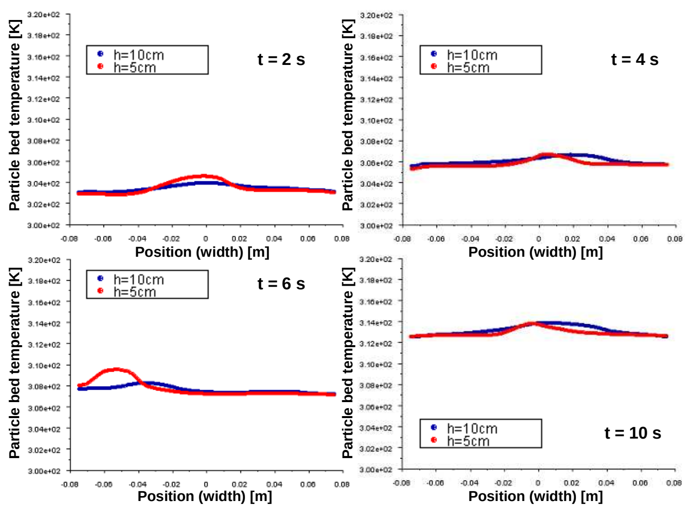
Conventional fluidized bed
Fluidization gas flow rate = 195 m^3 / (h·$m_{length\ fluid.\ chamber}$)

PARTICLE BED TEMPERATURE UNIFORMITY



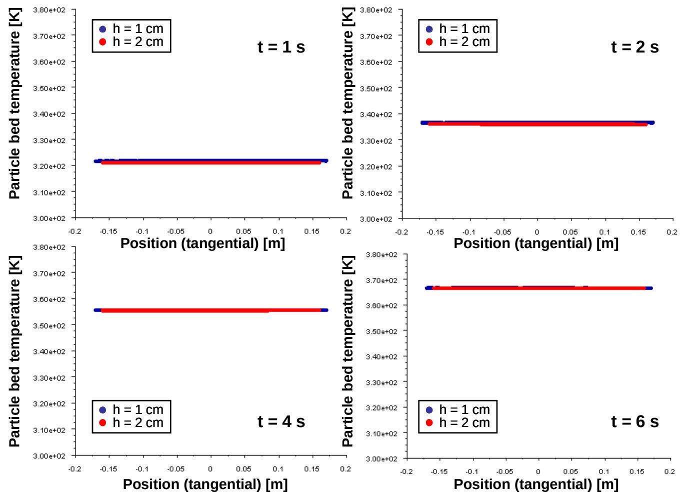
Conventional fluidized bed
Fluidization gas flow rate = 540 m^3 / (h·$m_{length\ fluid.\ chamber}$)

PARTICLE BED TEMPERATURE UNIFORMITY



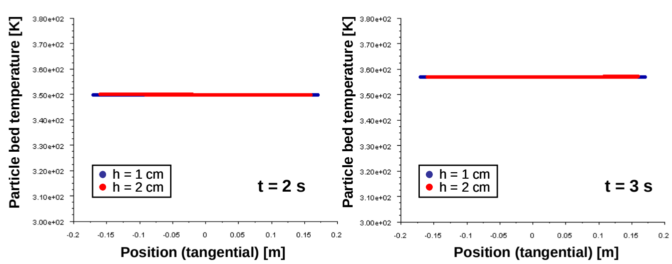
Conventional fluidized bed
Fluidization gas flow rate = 1080 m^3 / (h·$m_{length\ fluid.\ chamber}$)

PARTICLE BED TEMPERATURE UNIFORMITY



Rotating fluidized bed in a static geometry
Fluidization gas flow rate = 29800 m^3 / ($h \cdot m_{length\ fluid.\ chamber}$)

PARTICLE BED TEMPERATURE UNIFORMITY



Rotating fluidized bed in a static geometry
Fluidization gas flow rate = 59600 m^3 / ($h \cdot m_{length\ fluid.\ chamber}$)

IMPROVED PARTICLE BED TEMPERATURE UNIFORMITY, DUE TO TANGENTIAL FLUIDIZATION PARTICLE BED, i.e. THE PARTICLE BED ROTATIONAL MOTION

CONCLUSIONS

CFD SIMULATIONS CONFIRM THAT ROTATING FLUIDIZED BEDS IN A STATIC GEOMETRY:

- **Offer an increased specific fluidization gas flow rate**
- **Offer increased flexibility with respect to cooling or heating via the fluidization gas flow rate**
- **Offer the potential of gas-solid heat and mass transfer coefficients one to several orders of magnitude higher than in Conventional Fluidized Bed.**
- **Offer improved particle bed temperature uniformity due to excellent mixing resulting from the particle bed rotational motion**

⇒ PERSPECTIVES FOR USE OF ROTATING FLUIDIZED BEDS IN A STATIC GEOMETRY FOR FAST, HIGHLY ENDO- OR EXOTHERMIC REACTIONS OR FOR DRYING APPLICATIONS