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
  • STEP RESPONSE TECHNIQUE
  • CONVENTIONAL FLUIDIZED BED
  • ROTATING FLUIDIZED BED IN A STATIC GEOMETRY
• CONCLUSIONS
FLUIDIZED BED PROCESS INTENSIFICATION

- Improve external heat and mass transfer (between gas & solids)
- Improve internal mass transfer
- Reduce gas-solid contact time
- Increase ratio freeboard surface to bed height
- Reduce gas-solid contact time
- Increase bed height & increase gas velocity
- Increase ratio freeboard surface to bed height
- Cylindrical geometry

FLUIDIZE IN A CENTRIFUGAL FIELD
THE CONCEPT
36-cm DIAMETER FLUIDIZATION CHAMBER

- 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

THE CONCEPT
CRITERIA FOR STABLE AND UNIFORM OPERATION

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

(De Wilde & de Broqueville, 2007)
FLEXIBILITY IN THE FLUIDIZATION GAS FLOW RATE

- 1G-GELDART D-TYPE PARTICLES
- 24-cm DIAMETER FLUID. CHAMBER

Average radial gas-solid drag force
Average centrifugal force

LIMITED RADIAL BED EXPANSION, EVEN RADIAL BED CONTRACTION

GAS-SOLID HEAT TRANSFER COEFFICIENT

THEORETICAL INVESTIGATION

V = 0.01135 m³
Solids loading = 11.35 kg

h_f = 123 J/(m²·s·K)
### GAS-SOLID HEAT TRANSFER

**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 t₀**
- Eulerian-Eulerian approach with Kinetic Theory of Granular Flow
- Particles: 700 µm, 2500 kg/m³
- Restitution coefficients:
  - Particle - particle: 0.95
  - Particle - wall: 0.9
- Specularity coefficient: 0.5
- Solids loading: 33.75 kg/m³ length fluid. chamber
- **COMPARISON CONVENTIONAL FLUIDIZED BED AND ROTATING FLUIDIZED BED IN A STATIC GEOMETRY**
CONVENTIONAL FLUIDIZED BED

FLUIDIZATION GAS FLOW RATE

SOLIDS VOLUME FRACTION

195 m³/h
540 m³/h
1080 m³/h

ROTATING FLUIDIZED BED IN A STATIC GEOMETRY

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

SOLIDS VOLUME FRACTION

29800 m³/h
59600 m³/h

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

Rotating fluidized bed in a static geometry
Fluidization gas flow rate:
- 59600 m³/h (length fluid. chamber)
- 29800 m³/h (length fluid. chamber)

Conventional fluidized bed
Fluidization gas flow rate:
- 1080 m³/h (length fluid. chamber)
- 540 m³/h (length fluid. chamber)

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 m³/h (length fluid. chamber)
PARTICLE BED TEMPERATURE UNIFORMITY

Conventional fluidized bed
Fluidization gas flow rate = 540 m³ / (h m
length fluid. chamber)

PARTICLE BED TEMPERATURE UNIFORMITY

Conventional fluidized bed
Fluidization gas flow rate = 1080 m³ / (h m
length fluid. chamber)
Rotating fluidized bed in a static geometry
Fluidization gas flow rate $= 29800 \text{ m}^3 / \left( h \cdot m \text{ length fluid. chamber} \right)$

**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