Novel ICFAR solids feeder for pyrolysis and other applications - Experimental results, characterization, sequential modelling and optimization

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ICFAR Feeding Technology: Fundamentals & Modelling

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Conventional feeders for fluid bed reactors:

- **SCREW/AUGER FEEDERS**: plug when attempting to convey temperature-sensitive and cohesive feedstocks.

- **DILUTE-PHASE PNEUMATIC FEEDER**: require extensive carrier gas (increased compression energy requirements, condensation train challenges).

ICFAR INTERMITTENT SOLID SLUG FEEDER:

- Works with temperature-sensitive feedstocks.

- Moderate gas consumption \((F_s/F_g > 50)\).

- Enhances initial mixing of feedstock with hot bed.
ICFAR Feeding Technology

Motor

Bearing Assembly

Silo & Special Mixer

Pinch Valve

Feeding Port

 Slug Chamber Ex. #1:

 Slug Chamber Ex. #2:

Stand

Feeding Tube

Slug Chamber
1-20 kg/h
180-250 kg/h
THIS WORK:

• Slug characterization (length, mass, velocity, spreading) – using lasers
• Straggler detection (mass of stragglers)
• Modelling feeder slug flow
• Create and validate predictive model
## Selected Feedstocks

<table>
<thead>
<tr>
<th>Property</th>
<th>Units/Reference</th>
<th>DDG</th>
<th>MBM</th>
<th>BALL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sauter mean diameter</td>
<td>μm</td>
<td>577</td>
<td>25.14</td>
<td>15290</td>
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<tr>
<td>Bulk density</td>
<td>kg/m³</td>
<td>503</td>
<td>467</td>
<td>1229</td>
</tr>
<tr>
<td>Particle density</td>
<td>kg/m³</td>
<td>915</td>
<td>778</td>
<td>1229</td>
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<tr>
<td>Hausner ratio</td>
<td></td>
<td>1.26</td>
<td>&gt;1.35</td>
<td>1</td>
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<td><strong>Revolution Powder Analyzer:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Avalanche time</td>
<td>s</td>
<td>4.06</td>
<td>6.03</td>
<td>-</td>
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<tr>
<td>Avalanche median</td>
<td>s</td>
<td>4.29</td>
<td>6.50</td>
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<tr>
<td>Avalanche energy</td>
<td>kJ/kg</td>
<td>19.77</td>
<td>27.80</td>
<td>-</td>
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<tr>
<td>Energy std. deviation</td>
<td>kJ/kg</td>
<td>16.10</td>
<td>24.40</td>
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<tr>
<td>Avalanche angle</td>
<td>°</td>
<td>56.6</td>
<td>72.4</td>
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<tr>
<td>Rest angle</td>
<td>°</td>
<td>44.4</td>
<td>50.3</td>
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<tr>
<td><strong>Flow Characterization:</strong></td>
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<tr>
<td>Flow Type</td>
<td></td>
<td>Passable</td>
<td>Poor</td>
<td>Excellent</td>
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<td></td>
<td>Shah, 2008</td>
<td>Bhadra, 2009</td>
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</table>
Feeder Performance

![Graph showing Mass Fed (g) over Time (s) for MBM Fed and DDG Fed, with straight line fits for each.](image-url)
Feeder Performance

Straggler Accumulation vs. P

Slug Length vs. Tube Length

- Straggler Mass (g) vs. Pressure (Pa)
- Slug Length (m) vs. Feeding Tube Length (m)

Graphs showing data for different materials and pressures.
Modelling Approach
Model Assumptions

- Ideal gas law

- Delay for initial slug motion/friction (verified)

- No gas leakage through slug (verified)

- Friction factor feedstock index developed:
  - Quick experiments to determine
  - Can be scaled-up (future work)
Model Results for DDG

SLUG MOVES!

Graphs showing pressure and position over time.
Predictive Model for DDG

PREDICTED SLUG POSITION BY MODEL

- 240 kPa
- 308 kPa
- 377 kPa
- 446 kPa

SLUG Position (m)

Time (s)
The **ICFAR Intermittent Solid Slug Feeder** can feed temperature-sensitive and cohesive solids into fluidized bed reactors.

A **predictive model** for the feeder has been successfully developed by utilizing a sequential approach with validation from dedicated experimental data.

The predictive model can be used as a **design tool** to develop effective feeders for various applications, while considering physical constraints, capital costs and energy efficiencies.

Recent work has validated the model for the **large scale** feeder and for various **alternate feeder geometries**.
Thank you!

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