Fundamentals of rotating fluidized beds and application to particle separation

Justin M. Weber  
US Department of Energy's National Energy Technology Laboratory, justin.weber@netl.doe.gov

Richard C. Stehle  
US Department of Energy's National Energy Technology Laboratory ; Oak Ridge Institute for Science and Education

Ronald W. Breault  
US Department of Energy's National Energy Technology Laboratory

Larry Shadle  
National Energy Technology Laboratory, USA

Follow this and additional works at: http://dc.engconfintl.org/fluidization_xv
Part of the Chemical Engineering Commons

Recommended Citation
http://dc.engconfintl.org/fluidization_xv/60

This Abstract and Presentation is brought to you for free and open access by the Proceedings at ECI Digital Archives. It has been accepted for inclusion in Fluidization XV by an authorized administrator of ECI Digital Archives. For more information, please contact franco@bepress.com.
Fundamentals of rotating fluidized beds and application to particle separation

Justin Weber, Richard Stehle, Ronald Breault, Juray DeWilde
Typical Chemical Looping Process

**Fuel Reactor**
- CO₂/H₂O
- Fuel

**Carrier**
- Me
- MeO

**Air Reactor**
- O₂/N₂

**Reactor Types**
- Fluid Bed
- Spouted
- Moving
- Riser
- CFB

**Flow Directions**
- CO₂/H₂O → Fuel Reactor
- Me → Air Reactor
- O₂/N₂ → Air Reactor

**Partners**
- NETL
- B&W
- ALSTOM
The Problem: Solid Fuels

CO$_2$/H$_2$O → CO$_2$/H$_2$O

Coal → Carrier

Air Reactor

O$_2$/N$_2$ → O$_2$/N$_2$

Fuel Reactor

Carbon Stripper

Carbon/Ash
Let’s put some numbers on it!

550 MWₑ NETL System Study

Carrier  93,108,482 lbs/hr
Carbon   58,332 lbs
Ash      449,186 lbs
Total    93,616,000 lbs/hr

0.06%\text{w} Carbon!
0.14%\text{v}
Lets put it into perspective

Carrier

Carbon

Ash
Rotating Fluid Bed as a Separator?

Coal

\[ \text{CO}_2/\text{H}_2\text{O} \]

\[ \text{O}_2/\text{N}_2 \]

Fuel Reactor

Air Reactor

Carrier

Carbon Stripper

Carbon/Ash
Experiment

Vortex Chamber

Solids inlet
3D printed vortex chamber

38, 0.381mm slots
25 cm thick
12G – 59G
3D printed vortex chamber
System Layout

- Vortex chamber: 43 cm diameter
- Chimney (outlet): 10.2 cm diameter
- Solids Diverter: 40.6 cm diameter
- Gas inlets (x4): 5.5 cm diameter
- Solid Drain Ports (x3)
- Solid Feed Ports (x6)
- Pressure Ports (x10)
- Gas Inlet
- Chimney (outlet)
- Solids Diverter
- Gas Inlet
### Solid-Solid Separation

<table>
<thead>
<tr>
<th>Material</th>
<th>density (g/cm³)</th>
<th>d_{SMD} (µm)</th>
<th>d_{50} (µm)</th>
<th>sphericity</th>
<th>U_{mf} (cm/s)</th>
<th>particle mass (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Density Polyethylene</td>
<td>0.86</td>
<td>871</td>
<td>885</td>
<td>0.92</td>
<td>17.4</td>
<td>0.312</td>
</tr>
<tr>
<td>Glass Beads</td>
<td>2.51</td>
<td>329</td>
<td>333</td>
<td>0.92</td>
<td>9.47</td>
<td>0.049</td>
</tr>
<tr>
<td>Cork</td>
<td>0.19</td>
<td>797</td>
<td>835</td>
<td>0.8</td>
<td>9.37</td>
<td>0.058</td>
</tr>
</tbody>
</table>

**Centrifugal Force:**

- Particle mass dependent
- Force directed radially outward

**Drag Force:**

- Particle size dependent
- Force directed radially inward
Separated solids!

Cork

HDPE
**HDPE and Cork Separation**

- **Mixture feed at inlet**
- **Mixture collected at chimney exit**
- **Mixture from solids drain exit**

20% HDPE by particle count

98% cork by particle count

55% HDPE by particle count

*Glass Beads and HDPE did not separate*
Slugging
Video of slugging
Particle Velocity
Tangential velocity of 9.4m/s at a radius of 21.5cm; 45g
Drag vs Centrifugal Forces

Radial Gas Velocity:
Air volumetric flow rate 30,000 SCFH or 236,000 cc/s

\[ F_{c,p} = \frac{m_p v_{t,p}^2}{r} \]
\[ F_{d,p} = \frac{1}{2} \rho_g v_{r,g}^2 C_D A_p \]
Continued Work

Gas: Air
Pressure: 15 psi
Flow Rate:

Rotating Bed

Chimney Outlet
Filter
scale

Solid Outlet
Filter
scale

Feeder
Gas: Air
Pressure: 15 psi
Flow Rate:

Rotary Valve

Eductor

Control System: Labview
Disclaimer

- This project was funded by the Department of Energy, National Energy Technology Laboratory, an agency of the United States Government, through a support contract with URS Energy & Construction, Inc. Neither the United States Government nor any agency thereof, nor any of their employees, nor URS Energy & Construction, Inc., nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.