A twin-bed test reactor for characterization of calcium looping sorbents

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A TWIN-BED TEST REACTOR FOR CHARACTERIZATION OF CALCIUM LOOPING SORBENTS

Antonio Coppola, Fabrizio Scala, Liberato Gargiulo, Piero Salatino
Overview: the Ca-looping concept

CALCINER
T=850-950°C
CaCO₃(s) → CaO(s) + CO₂(g)

Auxiliary Fuel

CO₂

O₂

Fresh limestone (make-up)

Spent sorbent

CaO

CaO/CaCO₃

CARBONATOR
T=650-700°C
CaO(s) + CO₂(g) → CaCO₃(s)

Flue gas (with CO₂)

Flue gas (without CO₂)

N₂

Air

ASU
Overview: the Ca-looping concept

Sorbent-related Issues (1/2)

Decay of CO$_2$ Capture Capacity of the sorbent

- Sintering
- Presence of SO$_2$

CaO + SO$_2$ + $\frac{1}{2}$O$_2$ → CaSO$_4$
Overview: the Ca-looping concept

Sorbent-related Issues (2/2)

Attrition/Fragmentation Phenomena

- Primary Fragmentation
- Secondary Fragmentation
- Attrition by Abrasion

Few data on attrition of limestone during carbonation/calcination cycles are available in the literature (Blamey et al., 2010)
Overview: the Ca-looping concept

Lab-scale sorbent characterization studies

typical devices

thermogravimetric (TG) analyzers

attrition

single lab-scale fluidized beds

simulation of a continuous process

real thermal shock conditions

$\text{CO}_2$ capture capacity and attrition propensity
Aim of this work

a novel batch lab-scale apparatus is presented

realistic sorbent thermal history

two twin lab-scale bubbling fluidized beds

connected by a duct
**Experimental**

Scheme of the solid transport procedure between the two fluidized bed reactors.
Experimental
Experimental

Procedures and materials

<table>
<thead>
<tr>
<th></th>
<th>Limestone</th>
<th>Sand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass, g</td>
<td>20</td>
<td>150</td>
</tr>
<tr>
<td>Size, mm</td>
<td>0.4-0.6</td>
<td>0.9-1.0</td>
</tr>
<tr>
<td>v&lt;sub&gt;f&lt;/sub&gt;, m/s</td>
<td>0.4, 0.5, 0.6</td>
<td></td>
</tr>
<tr>
<td>h&lt;sub&gt;D&lt;/sub&gt;, mm</td>
<td>60, 55, 50, 45</td>
<td></td>
</tr>
<tr>
<td>h&lt;sub&gt;B&lt;/sub&gt;, mm</td>
<td>27, 32, 37, 42</td>
<td></td>
</tr>
</tbody>
</table>

German limestone (EnBW)

15 minutes for each stage

Evaluation of collection efficiency by PSD of the discharged material (by sieving)

\[
\eta, \% = \frac{\text{the amount of the transported material}}{\text{total amount initially charged in the bed}}
\]

Mass of transported sand
### Experimental Procedures and Materials

<table>
<thead>
<tr>
<th></th>
<th>N-RC</th>
<th>RC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sorbent</strong></td>
<td>Limestone</td>
<td>Lime</td>
</tr>
<tr>
<td><strong>Temperature, °C</strong></td>
<td>870/650</td>
<td>940/650</td>
</tr>
<tr>
<td><strong>CO₂ concentration, %vol</strong></td>
<td>100/100</td>
<td>0/0</td>
</tr>
<tr>
<td><strong>N₂ concentration, %vol</strong></td>
<td>0/0</td>
<td>100/100</td>
</tr>
<tr>
<td><strong>vᵣ, m/s</strong></td>
<td></td>
<td>0.5</td>
</tr>
</tbody>
</table>

**Operating conditions for hot tests**
Transport efficiency results – ambient conditions

**East bed**

- **vf, m/s**: 0.4, 0.5, 0.6
- **η, %**: 84, 86, 88, 90, 92, 94, 96, 98, 100
- **hB**: 42mm, 37mm, 32mm, 27mm

**West bed**

- **vf, m/s**: 0.4, 0.5, 0.6
- **η, %**: 84, 86, 88, 90, 92, 94, 96, 98, 100
- **hB**: 42mm, 37mm, 32mm, 27mm

**Graphs**

- **Transport efficiency results**
- **Ambient conditions**
Results

Transport efficiency results – ambient conditions

\[ \nu_f = 0.5 \text{m/s} \]
\[ h_B = 32 \text{mm} \]
\[ \eta \approx 95\% \]

20g of limestone and 150g of sand into the West Bed
86g of sand into the East Bed

\[ \eta \approx 95\% \] transferred sand \approx 64g
Results

Transport efficiency results – hot conditions

- N-RC (Limestone)
- N-RC (Lime)
- RC

Transport efficiency results

- Mass of transported sand, g

Cycle, -

80 85 90 95 100 105 110 115 120

80 85 90 95 100 105 110 115 120

N-RC (Limestone)
N-RC (Lime)
RC

Cycle, -
CO₂ capture and attrition results

![Graph showing CO₂ capture capacity and elution rate over cycles.](chart.png)
Results

CO₂ capture and attrition results – comparison with single FB experiments

TB = Twin beds (this work)
SB = Single FB experiments
Conclusions

Preliminary single-cycle and multi-cycle tests (at ambient temperature) showed good solid transfer efficiency results and the overall stability of the system.

Also at high temperature the system showed good stability both in terms of sorbent transfer efficiency and sand transportation.

Tests under non-reactive conditions pointed out the relevant role of the density difference between sorbent and sand.

The CO$_2$ capture capacity results exhibited a typical decay trend with the cycle number, as expected in a Ca-L process.

The comparison of these results with those previously obtained with the same limestone under comparable operating conditions in a single-bed apparatus pointed out capture capacity values higher than those of the single bed.

The particle attrition tendency is significantly dependent on the thermal history experienced by the sorbent. The absence of strong thermal shocks in the TB experiments leads in general to a decreased generation rate of fines.
Acknowledgment:

The Authors wish to thank Mr. Domenico Tinna (UniNa) for his support in carrying out experimental tests.