Effect of steam on the performance of Ca-based sorbents in calcium looping processes

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Effect of Steam on the Performance of Ca-Based Sorbents in Calcium Looping Processes

Antonio Coppola, Eduardo Gais, Gabriella Mancino, Fabio Montagnaro, Fabrizio Scala, Piero Salatino
Overview: the Ca-looping concept

Fluidization XV, May 22-27, 2016
- Québec, Canada

Effect of Steam on the Performance of Ca-Based Sorbents in Calcium Looping Processes
Overview: the Ca-looping concept

Sorbent-related Issues (1/2)

Decay of CO₂ Capture Capacity of the sorbent

- Sintering
- Presence of SO₂

Image:
- Chart showing the decay of CO₂ capture capacity over cycles.
Overview: the Ca-looping concept

Sorbent-related Issues (2/2)

Attrition/Fragmentation Phenomena

- Primary Fragmentation
- Secondary Fragmentation
- Attrition by Abrasion

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Overview: effect of steam

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# Experimental

**Lab-scale Fluidized bed (40mm-ID)**

**German Limestone (EnBW) (0.4-0.6 µm)**

4 complete cycles + 5° Calcination

<table>
<thead>
<tr>
<th></th>
<th>Calcination stages</th>
<th>Carbonation stages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>940°C</td>
<td>650°C</td>
</tr>
<tr>
<td>Test duration</td>
<td>20 min</td>
<td>15 min</td>
</tr>
<tr>
<td>Fluidization superficial velocity</td>
<td>0.7 m s⁻¹</td>
<td>0.6 m s⁻¹</td>
</tr>
<tr>
<td>Fluidizing gas composition (vol.)</td>
<td>70% CO₂+30% air</td>
<td>15% CO₂+85% air</td>
</tr>
</tbody>
</table>

**ste_cal**

| Fluidizing gas composition (vol.) | 10% steam+70% CO₂+20% air                             | 15% CO₂+85% air                                         |

**ste_car**

| Fluidizing gas composition (vol.) | 70% CO₂+30% air                                      | 10% steam+15% CO₂+75% air                              |

**ste_cal_car**

| Fluidizing gas composition (vol.) | 10% steam+70% CO₂+20% air                             | 10% steam+15% CO₂+75% air                              |
Results

![Graph showing results of dry, ste_cal, ste_car, and ste_cal_car conditions over four carbonation numbers.](image)

**Graph Legend:**
- **dry**
- **ste_cal**
- **ste_car**
- **ste_cal_car**

**X-axis:** Carbonation #
**Y-axis:** \( \gamma \) [g g\(^{-1}\)]
Results
Results

<table>
<thead>
<tr>
<th></th>
<th>$S_{BET}$ [m$^2$ g$^{-1}$]</th>
<th>$V_{TOT}$ [mm$^3$ g$^{-1}$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>dry</td>
<td>8.8</td>
<td>7.9 (1.1 micro+6.8 mesoporosity)</td>
</tr>
<tr>
<td>ste_cal</td>
<td>10.4</td>
<td>11.7 (4.9 micro+6.8 mesoporosity)</td>
</tr>
<tr>
<td>ste_car</td>
<td>8.4</td>
<td>8.2 (0.6 micro+7.6 mesoporosity)</td>
</tr>
<tr>
<td>ste_cal_car</td>
<td>10.1</td>
<td>10.2 (5.0 micro+5.2 mesoporosity)</td>
</tr>
</tbody>
</table>
Results

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di [mm]
0.0 0.1 0.2 0.3 0.4 0.5
cumulative x(di) [-]
0.0001
0.001
0.01
0.1
1
1st calcination
1st carbonation ...
2nd carbonation
3rd calcination
3rd carbonation
4th calcination
4th carbonation
5th calcination

a) dry
0.86±0.32%
b) ste_cal
0.72±0.42%
c) ste_car
0.96±0.27%
d) ste_cal_car
1.14±0.48%
Conclusions

- Steam is beneficial (CO₂ uptake)
- Calcination development of accessible porosity CO₂ uptake in the order of 10%
- Carbonation positive role of steam as a “catalyst” of CO₂ diffusion through the sorbent CaCO₃-based product layer.
- Calcination + carbonation: synergistic effects
- Fragmentation propensity: during calcination induces a more resistant external particle structure.
- Results highlight the positive role that the presence of steam in realistic calcium looping conditions
Thank you for your attention

**Acknowledgments**

Authors are grateful to Dr. Luciana Lisi and Mr. Luciano Cortese (IRC-CNR) for their support in carrying out porosimetric and SEM analyses.