Flow measurement of CO₂ streams with impurities by Coriolis flowmeter

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Aims and objectives
- The goal of project 1.1 is to investigate the performance of Coriolis mass flowmeter with high CO₂ content mixtures.
- To study the effect of impurities on the accuracy of the Coriolis flow meter.
- To investigate the performance of Coriolis flow meter at conditions likely to happen in the CCS operations.
- To investigate the accuracy of density measurement by Coriolis meter.

Key findings / outcomes
- The potential flowmeters for the transport of CO₂-rich mixtures in pipelines were reviewed. Coriolis meters were selected as an optimistic option because of high accuracy and ability to measure in both gas and dense phases [2].
- The fluid was transported through the Coriolis meter using pressurized air-driven pump from the source cylinder to the receiving facilities.
- The AVERAGE Absolute Relative Deviation (AARD) were obtained by comparing the measured mass collected in the receiving cylinders by robust weighing balance (±0.1 g) to the recorded mass by Coriolis meter.

Operational conditions and results of the tests with oxyfuel-ll gas mixture:

<table>
<thead>
<tr>
<th>Fluid</th>
<th>T/K</th>
<th>PMPa</th>
<th>ρ (kg.m⁻³)</th>
<th>mbar/g</th>
<th>mPa.s</th>
<th>Emorg</th>
<th>u%</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>293.4</td>
<td>2.08</td>
<td>81.6</td>
<td>0.05 MPa</td>
<td>90.95</td>
<td>0.1</td>
<td>0.09</td>
</tr>
<tr>
<td>CO₂</td>
<td>294.4</td>
<td>1.23</td>
<td>6.0</td>
<td>53.9</td>
<td>53.7</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>Pre-combustion</td>
<td>292.2</td>
<td>2.50</td>
<td>6.6</td>
<td>98.5</td>
<td>97.9</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Post-combustion</td>
<td>292.2</td>
<td>1.50</td>
<td>5.0</td>
<td>98.5</td>
<td>97.9</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

- Measurements of CO₂ were conducted with high accuracy [4].
- The AARD of 0.29% was achieved in validation tests using pure N₂ [4].
- Reference tests were performed using pure CO₂ at various P&T conditions and the AARD of 0.34% and 0.11% was obtained in the gas and dense liquid phases, respectively [3,4].
- Both impurities and transient operations can increase the uncertainties.
- The uncertainty of the Coriolis flowmeter in the measurements conducted with gas mixtures increased up to the AARD of 1.4% due to the presence of impurities [5,6].
- The uncertainty of the measurements in the full-scale range are expected to be in the range of EU-ETS requirements [5].
- The accuracy of the density measurements using Coriolis meter are under investigation.

Future work
- To study different flowmeters in the CO₂ transportation.
- To prepare a technical guideline for the CO₂ flow measurement in CCS.
- To investigate the effect of viscosity on the performance of Coriolis meters.

Compositions of the gas mixtures

Phase envelopes using Peng-Robinson Equation of State with CO₂ volume correction (PR-CO₂ EoS) [7]

Composition of the gas mixtures

<table>
<thead>
<tr>
<th>CO₂</th>
<th>O₂</th>
<th>H₂</th>
<th>N₂</th>
<th>Ar</th>
</tr>
</thead>
<tbody>
<tr>
<td>96.96</td>
<td>98.03</td>
<td>85.08</td>
<td>97.98</td>
<td></td>
</tr>
</tbody>
</table>

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Acknowledgement:

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