Dynamic and control of an absorber - desorber plant at Heilbronn.

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Abstract

The present work is a part of the EU OCTAVIUS project (Optimisation of CO₂ Capture Technology Allowing Verification and Implementation at Utility Scale) which aims to demonstrate integrated concepts for zero emission power plants covering all components needed for power generation as well as CO₂ capture and compression.

A test campaign using MEA was performed at the pilot plant at Heilbronn, Germany (Rieder and Unterberger, 2013) from November 2013 to March 2014 with a total of 1421 operating hours. The campaign included 6 test cases with transient step responses in steam, exhaust gas, solvent flow rate and finally a step in exhaust gas CO₂ content. In addition to single step responses, a test with simultaneous step in all flow rates (exhaust gas, solvent and steam) was also included into the test campaign.

The results from the test campaign showed that solvent compositional changes had very slow response due to the large solvent inventory in the plant. Lowering solvent flow rate further delayed the response. Reboiler steam flow rate correlated fast and stable with CO₂ production and internal desorber column gas temperature though with some exceptions. Simultaneous ratio responses in steam and solvent flow rate gave very little overall disturbance with a step in exhaust gas flow rate into the plant.

A dynamic model of the pilot plant was also developed and implemented in the dynamic simulation program K-Spice Simexplorer 2.9.1.0 (Kongsberg Oil & Gas Technologies AS). This model has been used to simulate the same step responses as in the pilot. In figure 1 the response of a 20% step reduction in liquid circulation rate is shown for the absorber outlet CO₂ concentration. The effect of the step response is very fast and effective in the beginning, but then almost disappears after some time due to changes in liquid CO₂ loading.

A comparison between of responses of the plant and K-spice model shows some steady state deviations, but the dynamics is very similar. This was typical also for the other tests performed.
Figure 1: Response in the CO\textsubscript{2} out of the absorber by 20\% step down in liquid flowrate.

In one of the tests a simultaneous and proportional reduction in flue gas flow rate, liquid circulation rate and reboiler duty (steam flow rate) was performed. The measured and simulated responses are shown in Figure 2 and show almost no effect on the CO\textsubscript{2} concentration in the gas out of the absorber.

Figure 2: Response in the CO\textsubscript{2} out of the absorber for a simultaneous step of 20\% in flue gas feed rate, steam rate and liquid circulation rate.

Since the K-Spice simulator was able to predict the transient trends with sufficient confidence and accuracy the K-Spice model was employed to investigate control configurations that could be implemented at Heilbronn pilot plant.
Two different control structures Con1 and Con2 were tested with the K-Spice model. Con1 was based on the results in Figure 2 with a ratio control such that the liquid flow rate and steam flow rate were changed in proportion to the amount of CO2 in the gas to the absorber. An extra feedback control loop was implemented to assure 90 % capture rate in a long term.

Con2 was based on the result in Figure 1 and uses the liquid circulation rate for the control of the recovery (CO2 out of absorber) and the steam flow rate (reboiler duty) for maintaining optimal conditions in the desorber. Close to optimal conditions could be obtained by keeping a internal temperature in the desorber column constant (Panahi and Skogestad, 2011, 2012).

The two configurations were tested in simulations with 30% changes in flue gas flow rate and CO2 composition as shown in Figure 3.

![Figure 3](image-url)

**Figure 3:** Feed gas flow rate changes at 3h and 6h. Absorber CO2 gas composition changes at 9h and 12h.

The responses in CO2 recovery are shown in figures 4 and 5.

![Figure 4](image-url)

**Figure 4:** Response in CO2 recovery (%) for configuration Con1.
**Figure 5:** Response in CO₂ recovery for configuration Con2.

**Table 1:** Statistics for the two control configurations

<table>
<thead>
<tr>
<th></th>
<th>Recovery %</th>
<th>SRD MJ/kg CO₂</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>std</td>
</tr>
<tr>
<td>Con1:</td>
<td>90.05</td>
<td>1.755</td>
</tr>
<tr>
<td>Con2:</td>
<td>90.00</td>
<td>0.521</td>
</tr>
</tbody>
</table>

In Table 1 the statistics during the simulations are shown. Both configurations showed good performance during the simulation testing, but Con2 was superior with respect to tight recovery control, which was excellent. The paper discusses how this might be an important property in a supervisory control scheme.

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**References**

