FLUE GAS CATALYSTS FOR WOOD COMBUSTION: TEST STAND RESULTS

Hans Bachmaier[1], Hans Hartmann[1], Christoph Schmidl[2]
[1]Technology and Support Centre in the Centre of Excellence for Renewable Resources (TFZ), Schulgasse 18, D–94315 Straubing, [2]BIOENERGY 2020+ GmbH Location Wieselburg, Gewerbepark Haag 3, A–3250 Wieselburg-Land

ABSTRACT: Small-scale wood stoves are a climate friendly and cost-effective solution for buildings with low energy demand. However, those appliances contribute significant shares of gaseous and particulate emissions all over Europe. The integration of an oxidation catalyst system into a stove can reduce emissions significantly. Aim of this study was to specify a method for precise evaluation of catalyst performance in logwood stoves under "real life" conditions in a cost- and time-saving manner. A test stand was developed allowing for the control of gas quality, flow rate and gas temperature according to the expected operation conditions of a catalyst. Conversion rates are evaluated directly by comparing emission concentrations of carbon monoxide, volatile organic carbon, methane and total suspended particles ahead and past the catalyst. Various tests were conducted to illustrate the performance of the test stand for catalyst evaluation. For each respective gas component, individual conversion rates were determined. Due to parallel measurements upstream and downstream of the catalyst, the usually high fluctuation in gas composition is not disturbing the accuracy of the measured conversion rates.
Keywords: catalyst, flue gas, wood, combustion, test stand

1 PURPOSE

Small-scale wood fired room heating appliances can be a climate friendly and cost-effective solution for new low-energy demanding buildings. However, small-scale wood stoves contribute significant shares of gaseous and particulate emissions all over Europe. The integration of an oxidation catalyst system into the stove can reduce such emissions significantly.

Evaluation of a stove-integrated catalyst is both complicated and time consuming as flue gas composition can only be determined downstream of the catalyst and, thus, repeated measurements are needed to compare the results to a stove without a catalyst. Therefore, the aim of this study was to develop a method to precisely evaluate catalyst performance for logwood stoves under "real life" conditions in a cost- and time-saving manner.

2 APPROACH

To simulate "real life" conditions for catalyst evaluation, a wood chip burner provides flue gas from wood combustion with high shares of gaseous and particulate emissions. Moreover, high flue gas temperatures and adjustable flow rates at the catalyst are needed. The newly developed test stand (figure 1) allows for the control of gas quality, flow rate and gas temperature according to the expected future operational conditions of a catalyst. The flue gas is generated in a burner for wood chips. Temperature and volumetric flow can be adjusted by bypasses and an integrated boiler.

Measuring sections ahead and past the catalyst allow for the extensive evaluation of conversion rates. In addition to carbon monoxide (CO), organic gaseous carbon (OGC), methane (CH4) and total suspended particles (TSP) are evaluated. To demonstrate test stand performance, test results of a honeycomb catalyst with noble metal coating are presented below (see results).

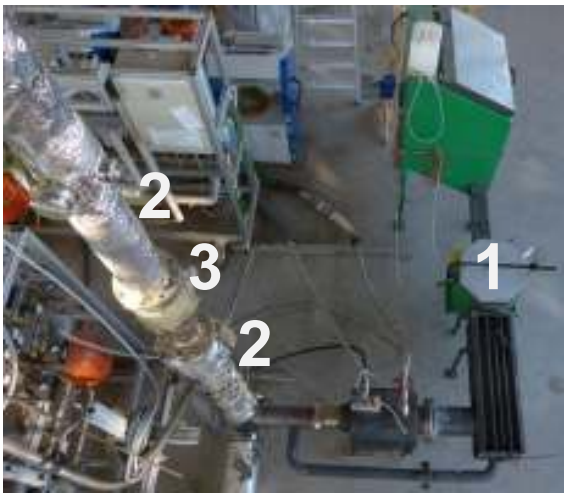

Figure 1: Test stand for catalyst evaluation with wood-driven flue gas generator (1) and measuring sections (2) up- and downstream of the catalyst (3)

Various tests were conducted to illustrate the performance of the test stand for catalyst evaluation. For each respective gas component (CO, OGC, CH4 and TSP), individual conversion rates were determined. By parallel measurements upstream and downstream of the catalyst the usually high fluctuation of gas composition does not disturb the accuracy of the measured conversion rates.

To exclude any emission reducing effects of the test stand, tests were conducted with a catalyst and with a catalyst dummy consisting of the original carrier material with identical geometry but without the catalytically active noble metal coating

3 RESULTS

Figure 2 and 3 show the temperatures ahead and past the dummy and the catalyst. For the dummy, downstream temperature slightly decreased (figure 2), whereas a slight rise in downstream temperature could be observed for the catalyst (figure 3). This increase is caused by the heat release due to the catalytic oxidation processes.

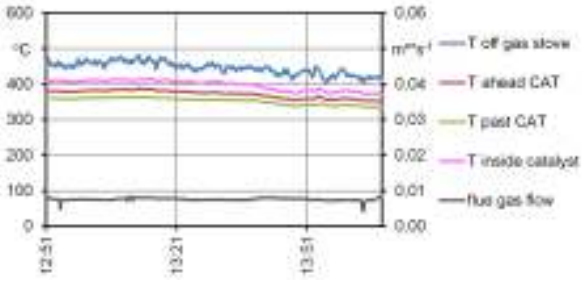

Figure 2: Temperature and flue gas flow at uncoated dummy carrier

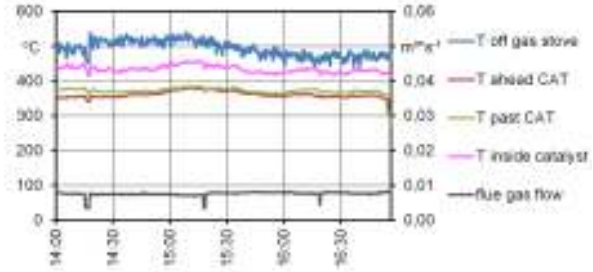

Figure 3: Temperature and flue gas flow at catalyst

CO concentration was not affected by the dummy (figure 4). At the same time, figure 4 verifies the good accordance of both CO measuring devices. In contrast to the dummy, the catalyst clearly reduced CO emissions (figure 5). At the same time the fluctuation range was narrowed.

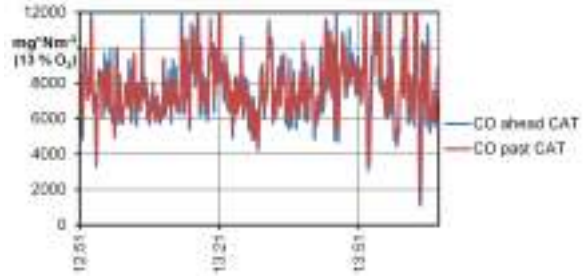

Figure 4: CO concentration ahead and past the uncoated dummy carrier

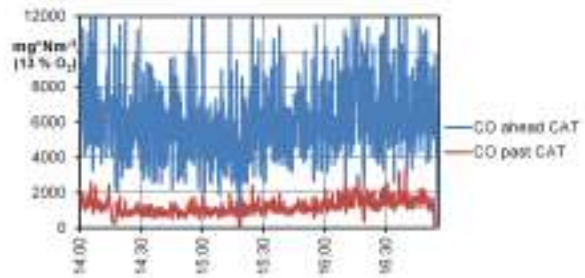

Figure 5: CO concentration ahead and past the catalyst

For organic gaseous carbons results were similar. While no effect could be observed for the dummy (figure 6), the catalyst achieved a considerable reduction of the OGC concentration (figure 7).

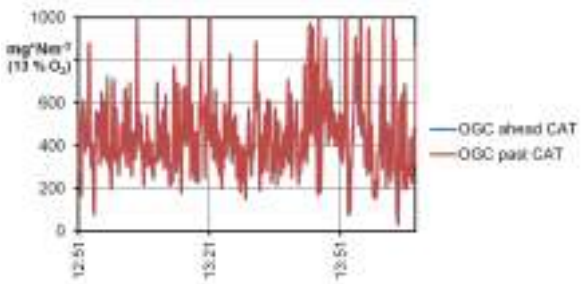

Figure 6: OGC concentration ahead and past the uncoated dummy carrier

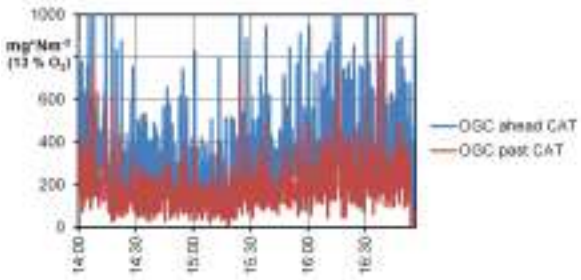

Figure 7: OGC concentration ahead and past the catalyst

The reduction rate was calculated by relating the cumulated mass past the catalyst to the cumulated mass ahead the catalyst. At the given temperature of about 350 °C the tested honeycomb catalyst reduced CO by 80 % (figure 8) and OGC by 48 % (figure 9).

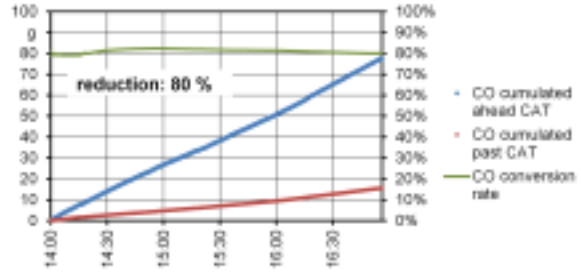

Figure 8: Cumulated CO-mass ahead and past the catalyst and resulting conversion rate

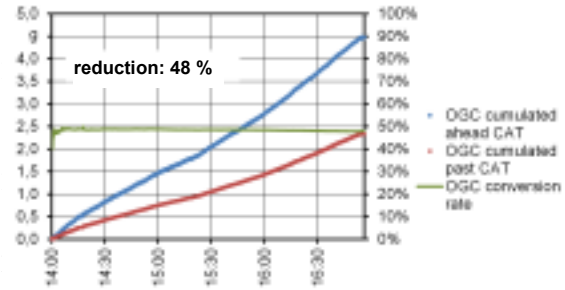

Figure 9: Cumulated OGC-mass ahead and past the catalyst and resulting conversion rate

The effect of the catalyst on TSP concentration was heterogeneous (figure 11). The catalyst reduced particles by a percentage of 12 to 36 % (figure 11). This effect is

probably caused by the oxidation of organic gaseous carbon. At a filtration temperature of 160 °C OGC condenses to some extent. This might also be the reason for the lower conversion rates in repetition 1, which corresponds with a lower OGC concentration in the raw gas at the beginning of the measuring period (figure 7).

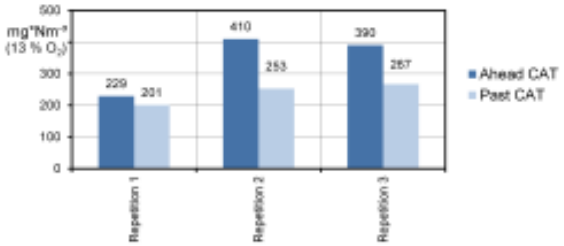

Figure 10: TSP concentration ahead and past the catalyst

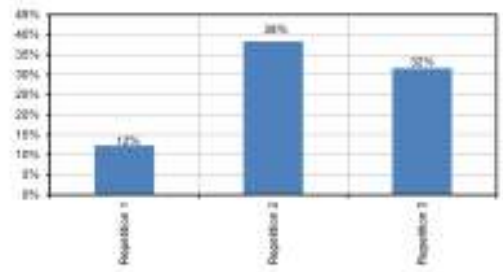

Figure 11: Differences in TSP concentration ahead and past the catalyst

Figure 12 displays the OGC conversion in high detail. Main component of OGC is methane. Methane does not condense at atmospheric conditions and does not affect human health in the given concentrations. The remaining OGC are composed of a large variety of substances. Some of these are considered toxic for human health. Therefore, the catalytic effect on non-methane-OGC is of special interest. The mean values per minute of the conversion rate (figure 12) show that methane is converted at low rates only. On the other hand the catalyst is able to convert non-methane OGC at higher conversion rates than the conversion rate for total OGC.

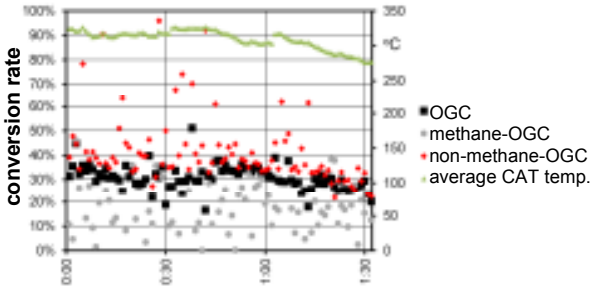

Figure 12: Conversion rates for total OGC, methane-OGC and non-methane-OGC

4 CONCLUSIONS

The test stand is deemed highly suitable for the evaluation of oxidation catalysts for flue gas from wood combustion. Thereby, the use of two parallel measuring sections contributed to a fast determination of gas specific conversion rates in real-life off-gas from wood combustion.

As the test stand demonstrates, a catalyst reduces the activation energy of oxidation processes and causes the post-combustion of gaseous pollutants from incomplete wood combustion. Operation temperature of the tested oxidation catalyst should be > 300°C. Thus, the installation close to the combustion chamber is necessary. At a sufficient operation temperature the catalyst reduces CO and OGC concentration considerably (CO by 80 %, OGC by 48 %). At high OGC concentrations, a certain effect on TSP reduction of up to one third can be observed. However, the low flow section of the honeycomb catalyst may lead to blocking by mineral particulate matter. This may require regular cleaning.

At the moment, catalysts are often used for cost efficient pollutant reduction in combustion units of older construction types to meet modern emission standards.

5 ACKNOWLEDGEMENTS

The research project “Clean Air Technology for Biomass Combustion Systems – BioCAT” was funded by the Seventh Framework of the European Union, Grant Agreement No. 286978.