Tar Reduction in Biomass Gasification Processes based on on-line Tar Measurements

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Objective

Still one of the most urgent problems encountered in taking biomass gasification to a commercial scale is the large amount of condensable organic species formed during the gasification process. [1] They cause severe problems in the downstream units and therefore need to be removed or converted into desired product gas species, ideally. The goal in the BioProGReSs project is the development, implementation and demonstration of an advanced syngas cleaning process based on chemical looping reforming, CLR.
In two work packages at TU Berlin a process model and a sensor is being developed for online measurements of organic species in the gas phase. Based on the models and the online measurements a process control strategy for the looping will be designed and the process will be scaled to a plant size of 100 MW_{SNG}. Also the economic benefits arising from the looping will be analysed and compared to state of the art technologies.

On-line Tar Monitoring

The on-line tar monitoring system which has been developed at TU Berlin uses fluorescence for quantitative and qualitative detection of organic species in hot product gas downstream of the gasifier. Tar molecules are excited by a light source.

While falling back into the non excited state each tar specie emits a very specific spectrum which is detected by the sensor. For the mobile monitoring device five LEDs with different excitation wavelengths were identified to cover the complete tar spectrum.

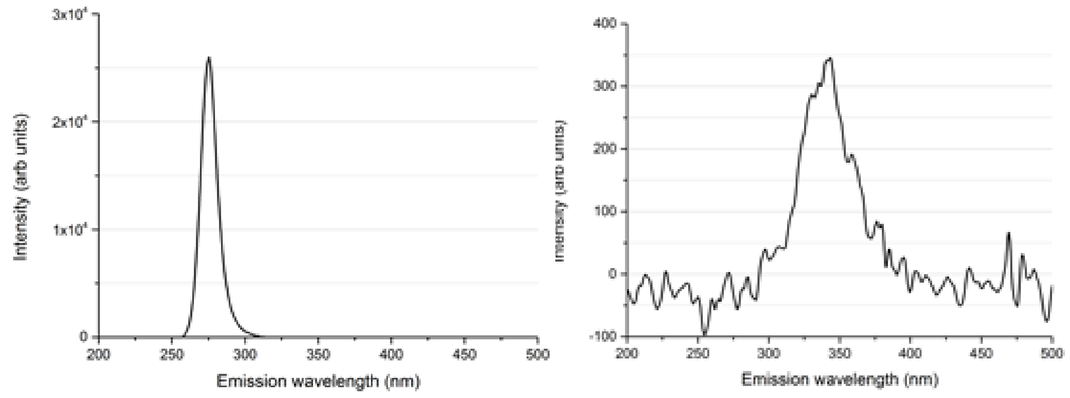

Figure 1: Emission spectrum of a 275 nm 1 mW UV-LED (left) and the corresponding emission spectrum of naphthalene excited by this wavelength

First Results with the Measuring Device

The aim of the on-line tar monitoring system was to build a measuring device which can be operated completely automatically and which discharges the off-gas directly inside the system so that no solid and liquid waste treatment is necessary.

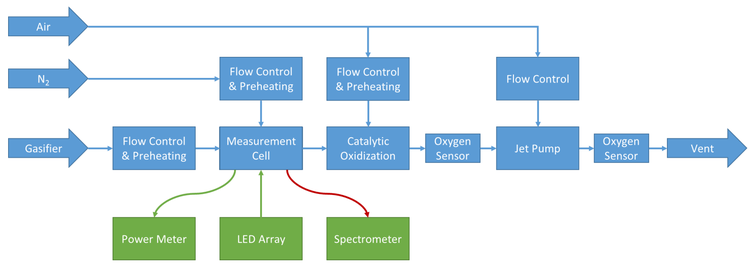

Figure 2: Setup of the measuring device

During first measuring campaigns at the gasifier at Chalmers University in Gothenburg the system was tested.

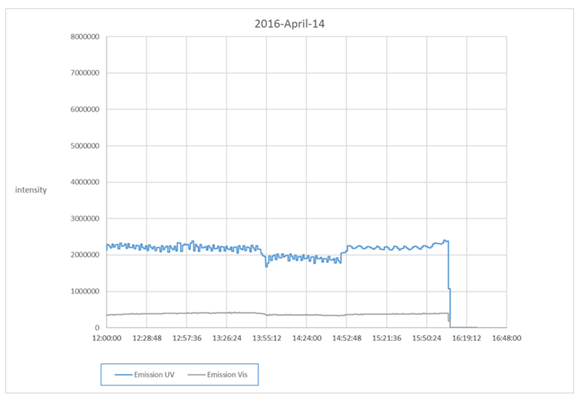

Figure 3: Course of the emission with <300 nm excitation wavelength; the change in gasification conditions at 13:55 and 14:52 have a significant effect on the detected signal.

Changes in the gasification conditions and thus in the gas composition were detected with the measuring device as shown in figure 3. Further optimization will lead to a measuring device which is capable of monitoring and controlling the process with very little maintenance effort.

Process Modelling

The process modelling at TU Berlin focuses on the optimization of the gas cleaning process downstream of the gasifier. The aim is to reduce operation costs significantly by finding the optimal combination of CLR, tar scrubber and absorption beds.
The exergetic losses and hence economic inefficiencies in the downstream units of a state of the art gas cleaning setup are displayed below.

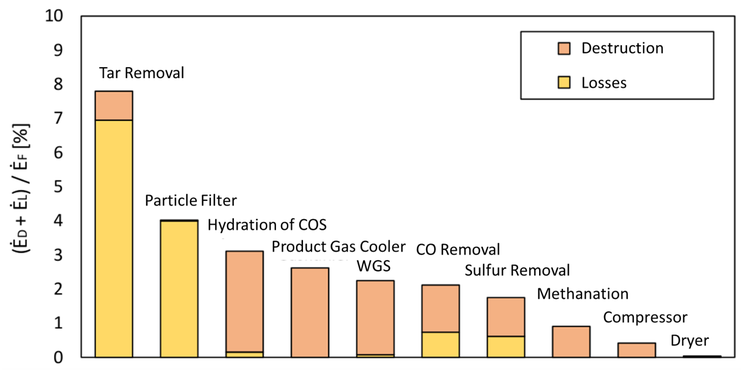

Figure 4: Exergy losses and destruction in the unit operations downstream of the gasifier in a biomass to SNG plant.

For the exergetic analysis a process model was designed in the simulation software CHEMCAD. A Visual Basic code calculates the exergy of each stream.

Economic Evaluation

The exergetic analysis shows very clearly that the tar removal step results in the largest penalty within the syngas cleaning. The CLR being currently demonstrated at the GoBiGas plant in Gothenburg aims at minimizing this penalty. At TU Berlin process designs using the CLR technology to transform these undesired organic species into desirable products are being designed and compared.

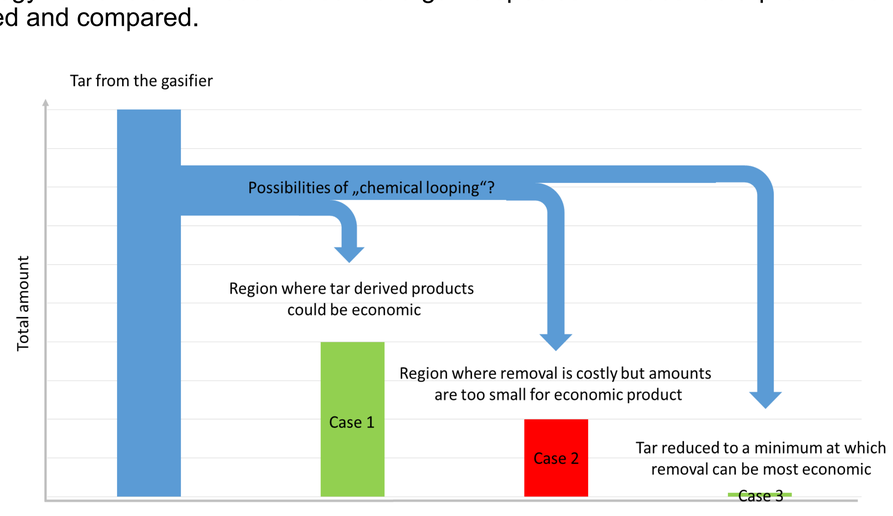

Figure 5: The effect of tar reforming possibilities on economic performance of the tar removal.

Figure 5 shows different possibilities how the CLR can influence the tar load in the product-gas.

While state of the art technologies are aiming at case 3 first calculations show that case 1 might be more beneficial for the overall economic efficiency of processes of larger scale (100 MW_{SNG}). Further research will focus on possibilities of combining chemical looping reforming and mature tar removal technologies and on economic dependency of these technologies with regard to plant sizes, especially for case 1 or case 3.

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[1] Neubauer, Y.: Strategies for tar reduction in fuel-gases and synthesis gases from biomass gasification. Journal of Sustainable Energy and Environment, 2011