Syngas production for DME synthesis from Sorption Enhanced Gasification of Biomass: A Pilot Plant-based Case Study

S.Hafner[1*], M.Schmid[1], G.Scheffknecht[1]

1. University of Stuttgart, Institute of Combustion and Power Plant Technology (IFK), Pfaffenwaldring 23, 70569 Stuttgart, Germany
*corresponding author, selina.hafner@ifk.uni-stuttgart.de

1. Introduction and Short Description:

For fulfilling the climate targets of the European Union, it will be necessary to reduce the use of fossil fuels significantly. Therefore, the development and optimization of technologies for the production of transport fuels such as Dimethyl Ether (DME) from renewable sources and waste streams is of main importance.

A very promising process for the production of the syngas that is needed for the synthesis of Dimethyl Ether is the sorption enhanced gasification (SEG). In this process, biomass is gasified in a dual fluidized bed reactor using a CaO-based CO_2 sorbent as bed material. The CaO absorbs the CO_2 ($CaO + CO_2 \rightleftharpoons CaCO_3$) that is formed during gasification, shifting the water-gas-shift reaction ($CO + H_2O \rightleftharpoons CO_2 + H_2$) towards the product side, leading to an enhanced hydrogen output. By adjusting the operational parameters (e.g. gasification temperature), a syngas with a Module M ($M = (y_{H2} - y_{CO2})/(y_{CO} + y_{CO2})$) equal to 2 that is optimal for DME synthesis, can be produced. The heat that is required for the endothermic gasification reactions is provided by hot circulating bed material from the combustion reactor and heat generated from the exothermic carbonation and water-gas-shift reactions. In the combustor, temperatures above 850 °C are achieved through burning unconverted char from the gasifier (and additional fuel if required) with air. Due to the high temperatures in the combustor, $CaCO_3$ is regenerated to CaO ($CaCO_3 \rightleftharpoons CaO + CO_2$), which is essential for CO_2 capture in the gasifier.

2. Methodology, Results and Discussion

The investigations were conducted in a pilot scale facility which consists of a bubbling (gasifier) and a circulating (combustor) fluidized bed reactor that are connected to each other. SEG experiments were performed with two different biomasses: wood pellets and pellets made out of the organic fraction of municipal solid waste (MSW). The composition of both biomasses is presented in Table 1.

Table 1. Chemical composition of wood pellets and pellets made out of the organic fraction of MSW

			Wood	**MSW**
Proximate analysis	γ_{H2O}	wt%,ad	6.0	8.0
	γ_{ash}	wt%,db	0.2	33.2
	γ_{V}	wt%,daf	82.7	90.0
	γ_{FC}		17.3	10.0
Ultimate analysis	γ_{C}	wt%,daf	50.8	53.9
	γ_{H}		6.1	6.4
	γ_{N}		0.2	2.5
	γ_{S}		0.1	0.6
	γ_{Cl}		0.0	1.0
	H_u	MJ/kg	17.4	11.6

Limestone with a nominal particle size distribution of 0.1 – 0.3 mm was used as bed material.
The experiments with both biomasses were conducted at a gasification temperature of 635 °C and a steam-to-carbon ratio of 1.5 mol/mol.
Standard gas components such as H_2, CO_2, CO and CH_4 and lower hydrocarbons (C_2-C_4) were measured continuously after fine filtration, washing in isopropanol (for tar removal) and condensation.
Tars were measured wet chemically according to the tar protocol [1].

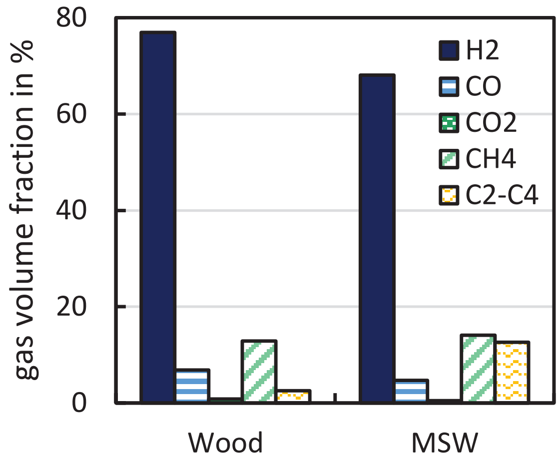

Fig. 1. Gas volume fractions of the syngas (N_2-free, dry basis) for SEG with wood and MSW

In Fig. 1, the N_2-free gas volume fractions on dry basis for H_2, CO, CO_2, CH_4 and C2-C4 are plotted for SEG with wood and MSW pellets. For SEG with wood pellets, a hydrogen concentration of 77 % has been reached, while the concentration for SEG with MSW was much lower with only 68 %. Another difference between the syngas obtained from the two biomasses is the C2-C4 concentration, which is much lower for SEG with wood pellets compared to SEG with MSW pellets (2.5 vs. 12.6 %). The same accounts for the gravimetric tar concentration. For SEG with wood, a gravimetric tar concentration of 19 g/m³ (STP) was measured, which is much lower than the 31 g/m³ (STP) that have been measured while using MSW. Both tar values have been measured at a gasification temperature of about 655 °C.

3. Conclusion and Outlook

The presentation covers results achieved from SEG with wood pellets and pellets made out of the organic fraction of municipal solid waste. Results are presented comprehensively focusing on syngas composition, considering standard gases (H_2, CO, CO_2 and CH_4), lower hydrocarbons (C2-C4) and tars. It is shown that the facility can be operated stably with both investigated fuels and that both fuels are suitable for the production of a syngas with a Module M equal to 2 that is required for downstream DME synthesis.

4. Acknowledgement

The FLEDGED project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 727600.

5. References

[1] DIN CEN/TS 15439:2006-08, Biomass gasification - Tar and particles in product gases - Sampling and analysis.