Generation of gaseous fuel for combined heat and power from woody biomass

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1 Summary

The multi-conceptual approach of our research group to investigate thermochemical conversion processes of biomass for production of heat and power is presented. Representative results are shown regarding the characterization of heterogeneous secondary reactions during pyrolysis of thermally thick wood particles, as well as with respect to the combustion behavior in laminar diffusion flames of the potential product gases.

2 Motivation

Thermochemical conversion of lignocellulosic biomass is expected to significantly contribute to the energy mix in the upcoming years. This contribution can take place with the direct generation of heat and heat & power or with the production of biofuels for transportation. However, the production of transportation fuels from biomass with these processes is still very challenging, due to the highly demanding post-processing of the product to reach marketable conditions. At the same time, this approach requires large scale, highly quality-oriented controlled conversion processes in order to get acceptable efficiencies, introducing a new constraint regarding biomass supply.

On the contrary, the production of heat and power can be done in smaller scales with less challenging requirements, and it is in this field where the major contribution is expected to take place in the next years. Despite this, still some limitations need to be faced in this area, mostly related to the production of tars and particles. Independently of the conversion process (gasification or combustion) these need to be removed, either to avoid damage of downstream equipment or to fulfill emissions regulations.

The formation of these compounds is related to both the conversion process and performance and the feedstock to be used. Therefore, in order to be able to deal with them it is necessary to understand its formation mechanism and composition, by deeply understanding the conversion process itself, but also to determine how to convert them without intensive cleaning in order not to increase costs and reduce conversion efficiencies.

3 Approach

In order to address the aforementioned problems, the questions we try to answer are:

- What is the composition of volatiles (tars) taking part in the gas phase reactions, either in direct combustion or gasification conditions followed by combustion of the gas product?
- Which factors influence particle formation and how is possible to influence them in order to reduce the emissions?
- What is the combustion behavior of these complex mixtures of volatiles?

In the first case, taking into account that for gasification and combustion, the pyrolysis step has a direct impact on the composition of the released volatiles as well as on the char reactivity, a deep characterization of the pyrolysis process is intended. This is done at molecular, particle and reactor level. It is of special relevance for us to address the presence of heterogeneous secondary reactions, enhanced by big particle size, and the influence of alkali content and process conditions on these reactions, since they have a direct impact on volatiles composition and char reactivity.

With respect to the particle formation, it is important to distinguish between organic and inorganic particles. The first ones are related to non-optimal performance of the conversion process, therefore this topic needs to be correlated to the pyrolysis mechanisms and further understanding of the gas phase reactions for the different processes. With respect to the inorganic particles, they are related to

the inorganic content of the biomass, and its reduction implies an optimization of the process itself, together with an appropriate cleaning system. In both cases, understanding of the formation mechanism, composition, concentration and particle size distribution requires appropriate characterization techniques. In this case, spectroscopy techniques will be applied, being this still future work.

Regarding the combustion behavior of the gaseous products, experimental investigation is performed in laminar diffusion flames, using a counter flow burner. Spectroscopy techniques, including laser-induced fluorescence (LIF), laser-induced incandescence (LII), Rayleigh and Raman are applied to characterize temperature, species concentration and particle formation. Also mathematical modelling is developed in this field to further understand the combustion behavior of complex mixtures.

4 Results

In Fig. 1 some results regarding the characterization of the pyrolysis process are shown. On the left, it is shown the release of permanent gases as well as the release of species emitting fluorescence. Those species would be mainly poly-aromatic hydrocarbons (PAHs) and the source of their production during pyrolysis at temperatures below 500 °C would be probably heterogeneous secondary reactions. On the right, a pyrolysis mechanism describing these reactions is shown.

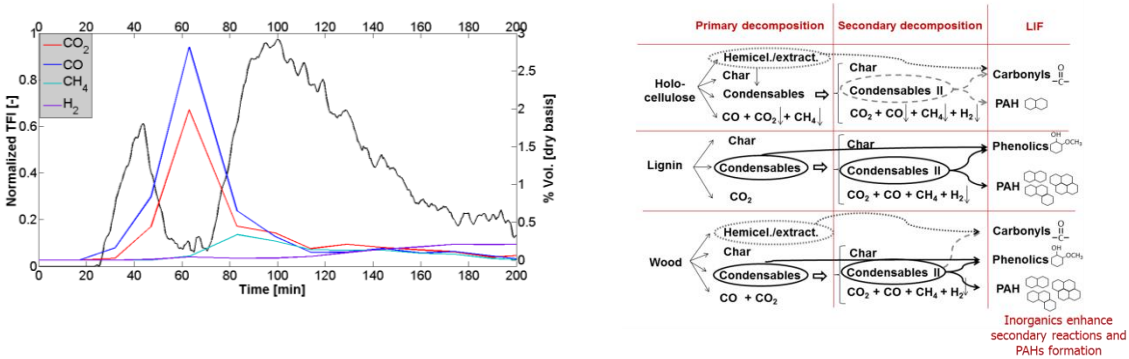

Figure 1: Left: Transitory evolution of permanent gases and compounds emitting fluorescence during slow pyrolysis. Right: mechanism proposed for slow pyrolysis [1].

In Fig. 2 it is shown the LIF and LII signals obtained during combustion of CH_4, taken as reference gas, during its combustion in the counter flow burner.

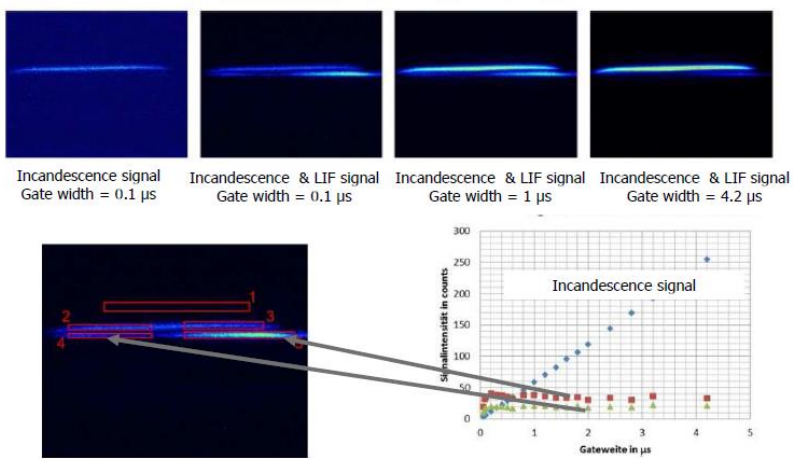

Figure 2: LII and LIF signal of a CH4 laminar flame

[1]Dieguez-Alonso, A. Anca-Couce, A., Zobel, N., Behrendt, F. Fuel 153 (2015)102-109.