Tandem-DMA measurements of gases and particles in large-scale biomass combustion and gasification

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Large-scale conversion of biomass may be used to produce heat, electricity and transport fuels, and it may thereby help limit our current dependence on fossil fuels. Industrial-scale combustion of biofuels has a number of challenges related to the heterogeneity, moisture and ash content of the feedstock, which may result in slagging and corrosion problems and reduced conversion efficiency. The alternative method of gasification of biomass provides a gas mixture, often referred to a synthesis gas, which may subsequently be transformed into methanol or methane in a catalytic process. Several gasification concepts are currently being researched and common problems relate to the unwanted production of tar components and the poisoning of catalysts by ash elements.

The further optimization of industrial combustion and gasification processes requires the development of methods that reliably and with high time-resolution measure the aerosol composition. On-line methods are of particular interest because of their use in process optimization, and as warning systems for high concentrations of unwanted components.

Here we present results from experiments where a volatility tandem differential mobility analyzer (VTDMA) was used to characterize particles and condensable components in combustion and gasification applications. Combustion studies where performed in a 12 MW_{th} circulating fluidized bed boiler (CFB) at Chalmers University of Technology (Davidsson *et al.*, 2007). Aerosol was sampled after the exit of the primary cyclone of the CFB at a gas temperature of 800 °C. Similar experiments were carried out at a 4 MW_{th} gasifier at Chalmers by sampling of the raw gas after the gasifier unit at an approximate temperature of 750 °C.

A sampling probe was used to extract gas from the reactors and the overall measurement strategy was to rapidly dilute and quench the hot sampled gas by mixing with an inert gas flow. The dilution results in rapid cooling of the gas and condensation of condensable components on existing particles, or nucleation of new particles. Different probe designs were evaluated with respect to sampling efficiency and effects of wall losses.

A narrow particle size range was selected by a DMA run in re-circulating mode with either air or nitrogen for combustion and gasification, respectively. The size-selected particles were directed through an oven that was ramped between room temperature and 800 °C, and the size distribution after the oven was characterized with a scanning mobility particle sizer (SMPS).

Figure 1 shows typical SMPS size distributions obtained for different oven temperatures when sampling from the CFB combustion boiler during feeding with wood chips. The size-selected particles begin to evaporate above 500 °C, which is consistent with a major KCl fraction in the detected particles. Size distributions measured at different oven temperatures were used to produce thermograms that display the remaining particle fraction as a function of temperature. Thermograms for selected compounds were also characterized under laboratory conditions, and the results were used to identify major aerosol components in the hot-gas experiments. Corresponding gasification studies were carried out with emphasis on the characterization of tar and inorganic compounds.

The studies confirm that the VTDMA method can be used to characterize both particles and condensable gases in combustion and gasification, and the potential of the method for industrial applications is discussed.

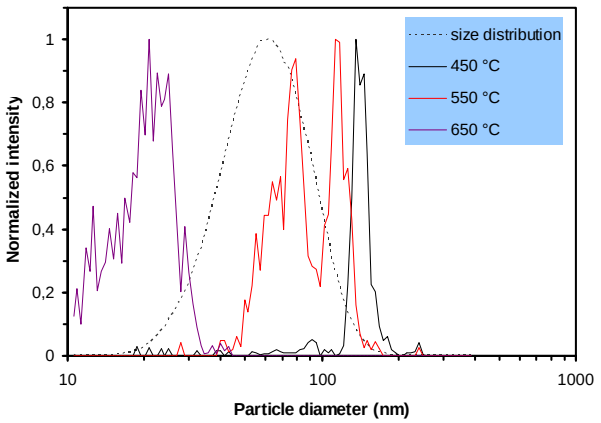

Figure 1. Normalized number size distributions obtained during combustion of wood chips in a 10 MW_{th} CFB: total particle size distribution (dotted line), and distributions measured with pre-selected 150 nm particles using the VTDMA setup at three different temperatures (solid lines).

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