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Online Particle Size And Concentration Measurement In A Pressurized Coal Combustion Process

Keywords: optical particle counter (OPC), online in situ measurements at high temperatures

Objectives and Approach

The energy industry has to face the demand for highly efficient coal combustion power plants in order to minimize the CO_2 emissions. Efforts are made in new combustion processes, where coal powder is burned at a temperature of 1400 °C and a pressure of 16 bars. The hot flue gas is used for a combined gas and steam turbine process. For that reason the flue gas has to be cleaned at the operating temperature and pressure. Limiting values for a secure operation of the turbine, with acceptable abrasion of the blades by impacting particles, are a mass concentration of $c_M \leq 3\,mg/m_N^3$ at particle sizes smaller than $3\mu m$. A granular bed filter is used to remove the gross of fine ash particles. But until now the separation of the submicron aerosol particles at high temperatures does not meet the mentioned specifications, and is still one of the most important open tasks. Regardless what kind of separation process will be implemented to remove fine ash particles, for investigations and control it is necessary to determine the particle concentration and size after the separation. The fact that the particle concentration after the purification is quite small and the size of the particles is less than 10 µm means that gravimetric measurements are not suitable to record spontaneous changes due to the combustion process because of extended sampling times. Additionally a gravimetric measurement technique at operating conditions (T = 1400 °C, p = 16 bars) is questionable, because particles can be lost by thermophoretic transport to the walls, also condensation of alkali species on the particle surfaces cannot be avoided (representativity).

The single-particle-light-scattering size analysis is especially suited for measurements at low particle concentrations ($< 10^5 particles/m^3$). With the counting technique used here, single particles are detected in situ while passing an optically defined measuring volume, which is placed in an iso-kinetically taken sample flow (free working distance of 80 mm and more). The total detectable size range of such a particle counter is between 0,1 and 10 µm. Based on previous successful measurements on the clean gas side of rigid ceramic barrier filters and at a coal combustion pilot plant at temperatures up to 1000 °C a constructive solution of this method at high temperatures *and* pressures is favourable.

Results

First measurements with a special optical particle counter were done at two industrial small-scale pilot plants, an atmospheric as well as a pressurized coal combustion process plant (AKSF and DKSF). Here, measurements at different high temperatures (600 °C and 1000 °C) were undertaken, but in the case of the pressurized coal combustion process, after flue gas expansion, also at atmospheric pressure. Next to the single-particle-light-scattering size analyser a Berner low-pressure impactor was utilized. In both test series the particle size distributions and concentrations of the ash particles on the clean gas side were determined. The following figure shows an example of the number distributions, ranging from 0,2 µm to 5 µm.

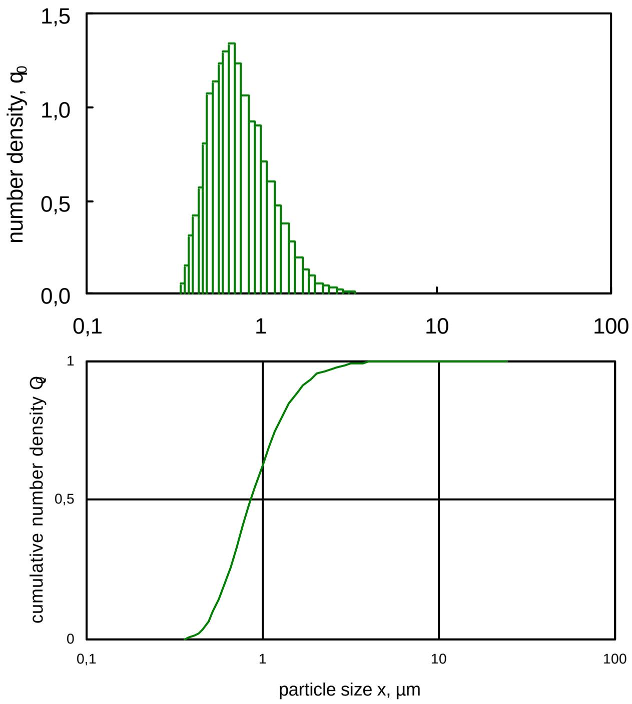

Fig.: Number density and cumulative number distribution as a function of the particle size

The mass concentrations did not fall below $100 mg/m_N^3$, the corresponding particle number concentration amounts to $3,1 \cdot 10^{10}$ $particles/m_N^3$, therefore the flue gas had to be diluted for the use of the counter. Nearly every result showed an interesting finding: a more or less distinctive bimodality of the mass distribution was found by the measurements with the OPC as well with the low-pressure impactor. Presumably the lower peak is due to the condensates. The fact, that smaller particles precipitate in the form of condensed alkali species, shows the necessity to perform in situ measurements at high temperatures. Supplementary to the measurements SEM-micrographs were taken and XRD-analysis were done of the filtered ash particles to characterize the particle morphology and chemical composition.

In addition, the capability of the optical particle counter to indicate spontaneous changes of the dispersed state of the flue gas aerosol was impressively confirmed. Though the results show that the currently applied granular bed filter reached the maximum tolerable particle size, the particle mass concentration still cannot gain the upper limit. Therefore an additional cleaning process is necessary to fulfill the limiting conditions.

Conclusions

Due to the further development of such an optical device, online in situ measurements not only at high temperatures (up to 1000 °C) but also at high pressures are intended.