Study of fine particle emissions from small scale wood chips combustion boiler

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Wood combustion in small scale boilers is widely used for domestic heating. The boiler capacity, combustion conditions, fuel quality, etc. strongly influence on particle emissions from the facility. Due to progress of combustion technologies particle emissions from small scale wood combustion has decreased with respect to mass concentration. However, fine particles, which are associated with various diseases, still contribute significantly to the PM-burden in many cities, especially during winter heating period.

In Germany the Ordinance for Small Scale Combustion (1.BImSchV) regulates the level of particle emissions from biomass combustion facilities. According to the ordinance, starting from 01.01.2015, the particle mass concentration in the exhaust gas from modern small scale wood combustion boilers should be decreased from 100 mg/m_N^3 to 20 mg/m_N^3. So, a significant part of wood-fired boilers will require the improvement of combustion conditions and /or the use of the exhaust gas cleaning equipment.

The purpose of the current work is the study of fine particle emissions from small scale wood chips combustion boiler for different operation conditions and development of recommendations for enhancement of the efficiency of the gas cleaning equipment.

The long-term experimental studies were carried in the Karlsruhe Institute of Technology. The test facility consisted of a 100 kW wood chips boiler (Fa. HDG Bavaria) which was equipped with automatic system for fuel delivering into the combustion chamber. The wood-chips combustion boiler was tested during 2 measurements companies, every ca. 1000 h.

For control of fine particles emissions from the exhaust gases a novel form CAROLA© space charge electrostatic precipitators (ESP) were applied. The ESPs are designed by the CCA – Carola Clean Air GmbH.. The boiler and the electrostatic precipitators were operated in automatic non-stop regime.

The exhaust gas from the boiler was delivered into the test set-up gas duct which allowed the control of the operation conditions, such gas flow velocity and temperature, exhaust gas composition and particle mass concentration (measured by the corresponding equipment from Fa. Wöhler) and particle number concentration (measured by the Scanning Mobility particle Analyser (SMPS), Fa. TSI). Among the measurements, also the chemical analysis and the REM-analysis of the collected material were carried out.

The studies show that the exhaust gas composition strongly depends on the combustion stage and it is characterised by the increase of the CO concentration by the start-up and burn-out stages.

During the 1000 h of boiler operation round 100 gravimetric measurements were carried out. The analysis of the results shows that the exhaust gas temperature and the particle mass concentration strongly depend on the fuel quality, type of burnt material and wood humidity. With increase of humidity, particle mass concentration in the exhaust gas flow increases. Reduced particle emissions (round 50-60 mg/Nm³) correspond to the wood humidity ca. 12-14%. The increase of humidity up to 23-25% results in the increase of particle mass concentration in the exhaust gas up to 150 mg/Nm³.

The results of SMPS measurements show (fig.1) that the mean particle size is 160-180 nm. The aerosol is three-modal, what probably corresponds to different combustion condition stages in the boiler with automatic delivering of wood into the combustion chamber.

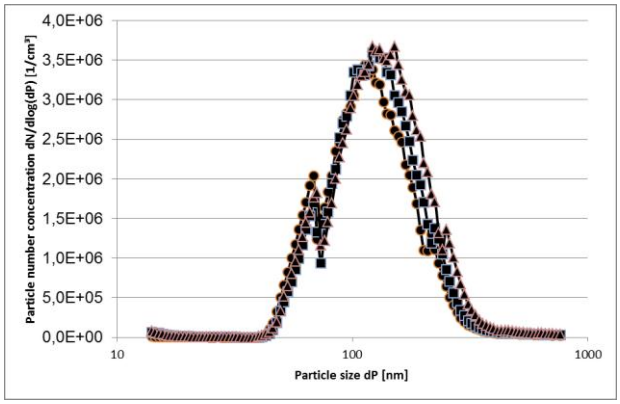

Figure 1. Example of particle size distribution in the exhaust gas flow, dilution factor 10

Among the discussion of the data of long-term observations of fine particle generation by wood combustion, the results of the reduction of fine emissions by the ESPs will be also presented. Detail results of the study of the electrostatic precipitators are the topic of the 2nd abstract presented by the EAC-2013.

The use of the novel ESP's strongly decreases particle mass and number concentration. The mass collection efficiency of the electrostatic precipitators is in-between 70% to 90% depending on combustion conditions.