Design and experimental study of a compact electrostatic precipitator

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Small-scale biomass combustion facilities are widely used for residential heating. Wood combustion results in undesirable gas and particulate emissions. Fine and ultra-fine fine particles, which are high in number concentration in the exhaust gas, contribute to PM-burden in many locations arising environment pollutions and health problems.

Different pollution control technologies are used for reduction of particle and gaseous emissions. The electrostatic precipitation is directed to the reduction of particulate emissions from the flue gases.

Usually, an electrostatic precipitator (ESP) is installed downstream or it is integrated into the combustion facility. The ESPs ensure high mass and fractional collection efficiency at low pressure drop and power consumption for particle charging and precipitation.

The aim of the current work is the design and experimental study of a compact and cost effective ESP for reduction of particulate emissions from small scale biomass combustion facilities. The ESP (Fig.1) is designed to be installed downstream the wood combustion boilers and stoves.

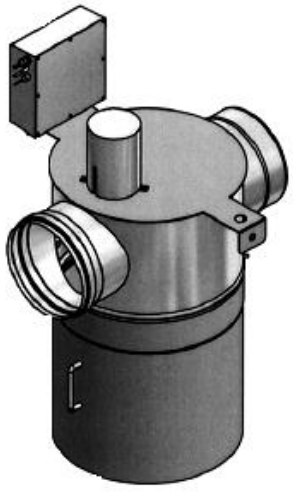

Figure 1. Compact electrostatic precipitator (CCA-Mini)

The precipitators (type CCA-Mini20, CCA-Mini60 and CCA-Mini100) are designed for exhaust gas cleaning with flow rates up to 16 g/s, 37 g/s and 63 g/s what corresponds to combustion facilities with heat capacity up to 20 kW, 60 kW and 100 kW, respectively.

The designed ESP includes a grounded casing with corresponding gas input and output. Particle charging takes place in the corona discharge double-stage ioniser. The applied high voltage insulator ensures stable operation of the ESP at various gas flow rates, temperatures, particle concentrations and exhaust gas composition.

Particle precipitation takes place under the influence of external electric field direct in the ionizing stages and under the influence of electrostatic space charge, thermo-phoretic and gas-dynamic phenomena in the ash-box, integrated into the ESP casing bottom part. The design supposes the collection of fly ash in the ash-box and periodical cleaning of the ESP after defined time of operation.

The electrostatic precipitator is equipped with a compact high voltage unit with smart control of the output voltage. In dependence of flue gas temperature, the high voltage power supply unit is switched on/off by a signal from a thermo-sensor installed at the ESP. It is confirmed the electro-magnetic compatibility of the designed electrostatic precipitator.

The results of the experimental study of the compact electrostatic precipitator for various operation conditions are discussed. The electrostatic precipitator was tested with various wood combustion facilities. Experimentally was investigated the influence of gas flow rate and temperature; applied voltage polarity, corona voltage and current, power consumption for particle charging and particle mass concentrations on ESP mass collection efficiency. The precipitator ensures long-term operation stability for exhaust gas cleaning at temperature up to 400°C and short-time operation at exhaust gas temperatures up to 500°C. The electrostatic precipitators ensure mean particle mass collection efficiency of ~73%. Depending on the combustion conditions and fuel quality, the ESP shows mass collection efficiency up to 90%.

The ESP design excludes any exit of exhaust gas from the casing during the operation. The ionizer is protected against any mechanical disturbance during gas duct cleaning upstream and downstream the precipitator. The electrostatic precipitator does not disturb the operation of apparatuses for direct measurement of particle mass and number concentration in the exhaust gas.