ESP for Small Scale Wood Combustion

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Abstract: In this paper new ESP technology developed for fine particle processes are presented. The ESP is based on diffusion charging of particles using sonic jet charger. The ESP concept has been tested using a commercial 20kW wood pellet burner. The removal efficiency was measured to be 80% for submicron particles.

Keywords: ESP, Precipitation, Aerosols, Submicron, Diffusion charging, Sonic jet, Wood combustion

1 INTRODUCTION

In large scale energy production based on combustion, most of the total mass is associated with the large (over 1 μm) particles. Interest in small (below 1 μm) or ultrafine (below 0.1 μm) particles has arisen from the health effects associated with them. As both, the large and the small/ultrafine particles, need to be removed filtering system needs to operate in a very wide range of particle sizes. This usually means larger collection area and increase in investment and operational costs.

However there are applications where most, if not all, of the particle matter is in the submicron size range. Typical examples are diesel engines, many aerosol processes (like coating) and wood combustion in modern wood pellet burners.

In the case of electrostatic precipitation there is no need to use field charging mechanism when there are no large particles present in the flue gas and the precipitator can be designed to rely on diffusion charging. This opens interesting new possibilities in the designs of the charging and the collecting devices.

The concern for global warming and the high energy price has increased the interest on biomass burning in small scale units also in European cities. Wood combustion decreases the net production of CO_2 but as a side effect it produces submicron particles that can locally cause health related risks. Recent development in furnace technology (improvements of geometry, combustion air control and position of inlets) has decreased the formation of large fly ash particles. Submicron particles are still a problem that has not been solved by the development of combustion technology.

2 SONIC JET CHARGING

Sonic jet charger is a device that can be used to produce large number of ion for charging aerosols. It was first introduced by Whitby in 1961 and it was successfully used as an aerosol neutralizer and in ion behaviour studies [3]. It has also been used in aerosol measuring devices as it has low particle losses and high charging efficiency [1].

Sonic jet charger has a chamber with a small orifice open to aerosol carrying duct. Co-centric with the orifice there is a corona needle that produces the ions (Fig. 1). The chamber has a supply of pressurised air that is purged through the orifice in sonic speed carrying the ions with it. Optimization of the corona needle position, corona voltage and sonic air flow thorough the orifice can give 100% efficiency in ion production [3]

Sonic jet charger has several advantages in electrostatic precipitation (ESP) applications. As the corona discharge is produced inside a separate chamber it is not influenced by the properties of aerosol flow. Parameters such as gas temperature, humidity and pressure that have an effect on corona operation can be optimized. There is also a dramatic decrease in problems associated with keeping the corona electrode clean as filtered air can be used. Changes in aerosol concentration in gas flow have no effect in corona operation. Corona can be operated with low constant voltage that keeps the power supply very simple.

ESP applying the sonic jet charger is a two stage device and so the collection section can also be optimized freely without influencing the charging process.

3 TESTING

3.1 Precipitator

ESP using the sonic jet charger and a plate type collector was installed in the flue gas line of a 20 kW pellet burner/ boiler combination. The sonic charger consist of an outer shell (200 mm long tube with a diameter of 26 mm) having a 2 mm diameter sonic orifice and connectors for compressed air and high voltage supplies. A sharp needle was used as a corona electrode. A 10 mm diameter rod was used as a conductor rail inside the charger to prevent unwanted corona discharge. The sonic nozzle is made of insulating material. The corona discharge is formed between the needle and the outer shell right after the nozzle.

The collector was located 1m down stream from the charger. It consists of 5 parallel plates hanging inside 30×30×30 cm casing. Plate separation from each other and from the casing was 5 cm (Fig. 2). The middle and the outmost plates were connected to high voltage source. Two remaining plates and the casing were grounded. In the field tests with pellet boiler 17 kV collection voltage was used resulting 3.4 kV/cm collection field strength of.

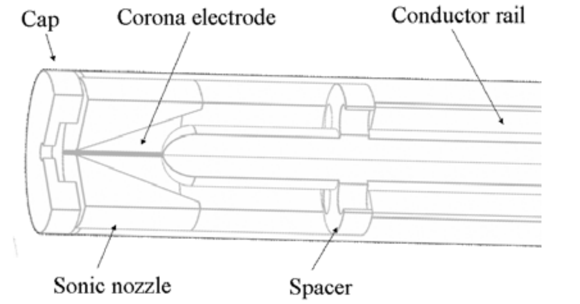

Fig. 1 Schematics of the charger

Fig. 2 The collector

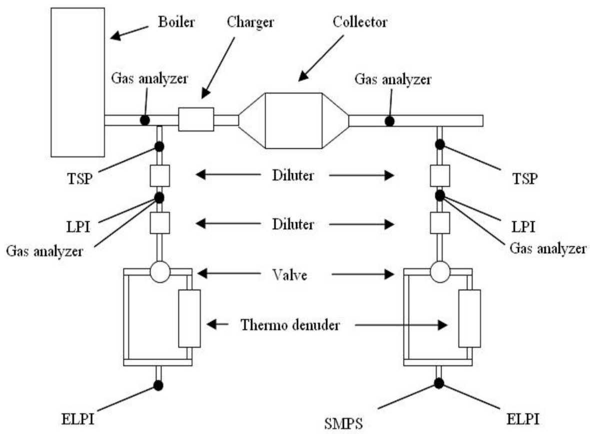

Fig. 3 The measurement system.

3.2 Measurement system

Aerosol concentration and distribution measurements were made up and down stream of the ESP. The measurements were made using standard filter collection for total suspended particle mass (TSP), low pressure impactors (LPI) for PM 10 mass distribution and scanning mobility particle sizer (SMPS) and electrical low pressure impactors (ELPI) for number distribution (Fig. 3).

TSP samples were collected from raw flue gas. As we had only one filter sampler available, TSP measurements up and down stream were not simultaneous. Real time devices were used to evaluate the accuracy of removal efficiencies calculated from TSP measurements.

LPI measurements were made using two identical sampling/dilution systems and impactors. Dilution systems were used to increase the sampling time to achieve more reliable results. Dilution ration was measured using gas analyzers.

ELPI measurements used the same sampling/dilution system as the LPI but had an additional ejector diluter.

SMPS system was mainly used to measure the amount of volatile components in the aerosol. Thermo denuders are part of these measurements and were not used in removal efficiency measurements. Volatility results are not presented here.

4 RESULTS

ESP removal efficiency can be calculated in two ways. In a first method the particle concentrations down and up stream of the ESP system can be used. When ESP is running the difference between these measurements shows the total decrease in particle concentration caused by the ESP unit. This value includes non-electrical losses in the system between measurement points and also the diluting caused by the sonic charger air flow. When ESP power is cut off this measurement gives the non-electrical losses and charger dilution. In this method small differences in the operation of the two sampling/dilution systems must be corrected in the calculations.

Second method is to calculate the precipitation efficiency from the down stream measurement by comparing concentrations in ESP on/off situations. This method has the advantage that it automatically cancels all effects not related to the ESP operation. On the other hand it can not be used if the boiler operation varies between the measurements. As the boiler operation was very stable, the removal efficiencies presented here are calculated by using the downs stream ESP on/off method.

4.1 Charging efficiency

Sonic jet chargers are known to have very good charging efficiency for ultrafine particles [2]. Our laboratory tests show, that up to 1μm particle size, the sonic jet charger can produce particle charge ratios comparable to traditional wire-plate chargers (Fig. 4). This behavior is what is expected from the charging theory. Above 1 μm field charging has a dominating effect in wire-plate chargers.

Corona current has only a minor effect in the charging efficiency in sonic jet charger. Increase in corona current increase the voltage between corona and ground electrodes and a larger fraction of the produced ions are lost inside the charger.

Increase in the charger air flow rate results in increasing charging efficiency. However when the air flow is above a certain value increase in flow rate does not anymore result increase in charging efficiency. This upper limit depends on charger dimensions and geometry.

In our charger unit optimal charging performance in room temperature was achieved using 6kV corona voltage with 13 μA corona current. Optimal air flow rate was 30 lpm with 2.5 bar applied pressure.

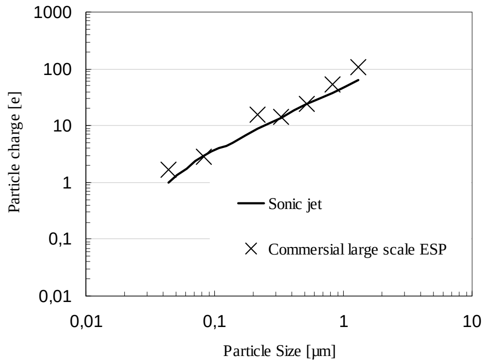

Fig. 4 Charging efficiency of the sonic jet charger. Charging efficiency of a commercial large scale ESP is given for comparison.

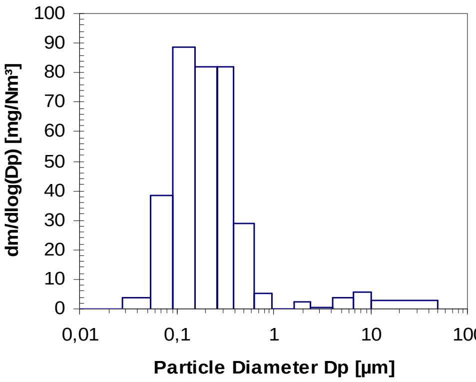

Fig. 5 Particle mass distribution from the boiler. TSP from the boiler was 75–85 mg/Nm^3

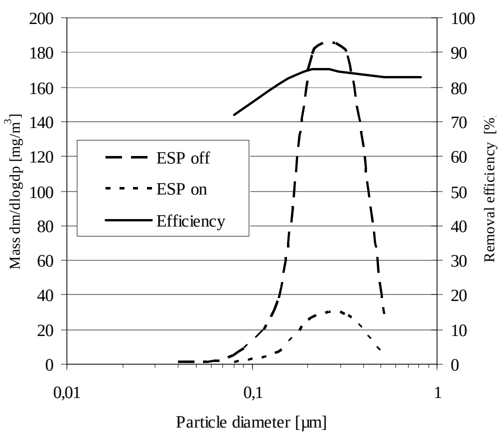

Fig. 6 ESP removal efficiency distribution for particles below 1 μm. Figure also shows particle mass distributions in ESP on and off situations (calculated from ELPI number distributions)

4.2 Removal efficiency

The particle distribution from the pellet boiler was ideal for testing the sonic jet charger based ESP. 90% of the total mass was in particles below 1μm. Total suspended particle load was 75–85 mg/Nm^3 (Fig. 5.). Flue gas flow rate from the boiler was around 1m^3/min (135 ℃). After ESP the TSP dropped down to 15 mg/Nm^3. This gives a removal efficiency of 80%. Other measuring method (LPI and ELPI) gave similar results (Fig. 7).

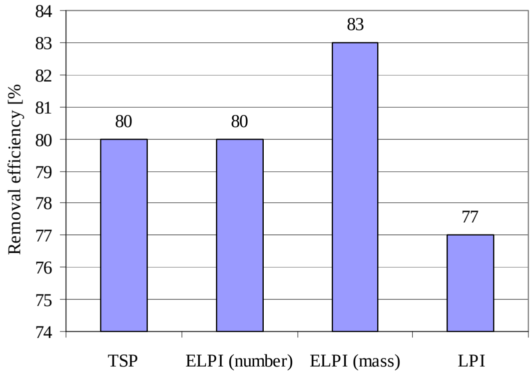

Fig. 7 Comparison of the calculated ESP particle removal efficiencies using different measuring techniques

5 CONCLUSIONS

Two stage ESP system with sonic jet charger and a parallel plate collector was developed and tested with commercial wood pellet boiler. The results show that this type of ESP system can successfully be used in applications where major part of the aerosol particles is in the submicron size range. The developed ESP system is compact, inexpensive and can be made nearly maintenance free. These are very promising features when considering domestic use.

The system can be scaled up using the same principles as with normal one stage wire to plate ESPs to achieve higher precipitation rates or to handle larger air flows.

This technology can find use in applications were normal ESP becomes too expensive as it has considerably lower investment cost. It may also be used as an additional charger with normal ESP to enhance its submicron particle removal efficiency.

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