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Performance of a sonic jet-type charger in high dust load

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ABSTRACT

Sonic jet chargers have originally been used in aerosol measurement devices for particle charging and neutralization. Here, our goal was to study if this charger type could be used in particle control devices in which particle concentrations and gas volumes are much higher. The study includes charging efficiency tests in a laboratory and with a commercial 20 kW wood pellet burner. Actual particle removal efficiency was tested with a laboratory scale parallel plate electrostatic collector. The results show that sonic jet-type chargers also have potential in filtering applications.

1. Introduction

Historically, electrostatic particle filtering technologies have been used in applications that produce high amounts of large (over 1 μm) particles. A typical example is a large-scale energy production facility based on coal combustion [15]. Fine particles have very little mass and thus were not considered to be a problem as emission regulations was and still are mainly based on total mass. The increasing knowledge of severe health effects related to fine particles has changed the situation [1,9]. New clean air regulations cover applications that were not considered harmful some years ago.

Traditional electrostatic precipitators (ESP) are naturally optimized to remove large particles. In a single-stage ESP, particle charging and removal processes are combined; therefore, charging takes place in high electric field conditions. This enhances the field charging process, and large particles acquire high particle charges. On the other hand, field charging is not a very effective mechanism for fine particles, which are mainly charged by a diffusion charging process, even in high field conditions. Efficient charging of fine particles requires large amounts of free ions and long residence times. This leads to larger volume requirements and more expensive ESPs.

High field conditions are not necessary for efficient charging when no large particles are present in the flue gas. The precipitator can then be designed to rely on diffusion charging. This approach is valid with several applications, such as diesel engines, many aerosol processes (like coating) and biomass combustion in modern burners.

In traditional ESPs the discharge electrode is located in the flue gas flow path and the flue gas conditions have a direct effect in the discharge process. The chemical composition, temperature and particle load of the flue gas change the corona characteristic and can even prevent stable corona formation [12,16]. In the ion generation process free electrons formed in the vicinity of the negative corona electrode are attached to the electronegative gas components. An extreme case is nitrogen gas with negative corona: as the electrons can't attach to nitrogen, there is no stable corona operation regime and the corona starting voltage is also the gas sparkover voltage. In practical flue gas cleaning there is always several electronegative gases presents for electron attachment and the gas composition effects the ion mobility and corona operation.

Flue gas temperature and pressure effect the voltage window of stable corona operation between corona initiation and sparkover. Increase in temperature and decrease in pressure both lead to narrower range of suitable corona voltages. In applications with high temperature and pressure these two counterbalance each other and stable corona can be obtained. Corona charger operating at atmospheric pressure levels need to be modified at temperatures above 500 °C. With modification in electrode shape and electrification EPS's has been installed to work at temperatures up to 850 °C [13].

Aggressive chemical components in the flue gas can cause

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corrosion in the discharge electrodes decreasing their life time. High corrosion resist material can be used in these cases but with increased installation and running costs.

Part of the particle matter in the flue gas accumulate to the discharge electrode surfaces and needs to be cleaned regularly to ensure proper operation. Cleaning is typically done with the same rapping method as with collection plates.

A sonic jet charger is a device that can be used to produce a large amount of free ions to be used for the diffusion charging process. The main difference to normal corona electrodes is that the corona discharge electrode is not in contact with the flue gas but is located in a separated chamber. Corona discharge and ion formation takes place in a shield gas flow. Temperature, pressure and chemical composition of the shield flow can be adjusted to optimal corona operation. The use of sonic jet charger can open new applications for ESP based filtration where devices using traditional corona electrodes fail or fall in to problems.

1.1. *Sonic jet charger*

A sonic jet charger can be used to produce a large number of ions for charging aerosols. It was first introduced by Whitby in 1961 and was successfully used as an aerosol neutralizer and in ion behavior studies [17]. Sonic jet-type chargers have also been used in aerosol measuring devices, as they have low particle losses and high charging efficiency [5,10,14]. Particle charging is mainly based on diffusion charging, as the only electric field is the one generated by the ions and charged particles.

Sonic jet chargers have a chamber with a small orifice that opens to an aerosol-carrying duct. Co-centric with the orifice is a corona electrode that produces the ions. The chamber has a supply of pressurized air that is purged through the orifice. The ions are carried to the flue gas through the orifice by the near-sonic-speed purge gas flow.

Sonic jet-type chargers have several advantages in electrostatic precipitation applications. As the corona discharge is produced inside a separate chamber, it is not influenced by the properties of the 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 it operates in clean gas flow. Changes in the aerosol concentration of the gas flow do not affect the corona's operation. An ESP applying a sonic jet-type charger is a two-stage device; hence, the collection section can also be optimized freely without influencing the charging process.

Two versions of a sonic jet-type charger were used in this study (Fig. 1). The first one, with an integrated ground electrode (integrated grounded electrode charger/iGE charger) was introduced by Ref. [8]. It consists of an outer shell (a steel tube with a diameter of 26 mm) with a 2-mm diameter sonic orifice and connectors for compressed air and high voltage supplies. A sharp needle was used as a corona electrode. The corona electrode is also protected by a cap with a 3-mm diameter orifice. A 10-mm diameter rod was used as a conductor rail inside the charger. Insulating spacers keep the conductor rail and the corona needle co-centric. The sonic nozzle is made of insulating material. The corona discharge is formed between the needle and the ring electrode, which is electrically grounded via the outer shell.

An alternative design for the charger (external GE charger/eGE charger) consists of an electrically insulated outer shell (a ceramic tube with a diameter of 26 mm) with 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. Insulating spacers keep the conductor rail and the corona needle co-centric. The nozzle is made of insulating material. The corona discharge is formed between the needle and the

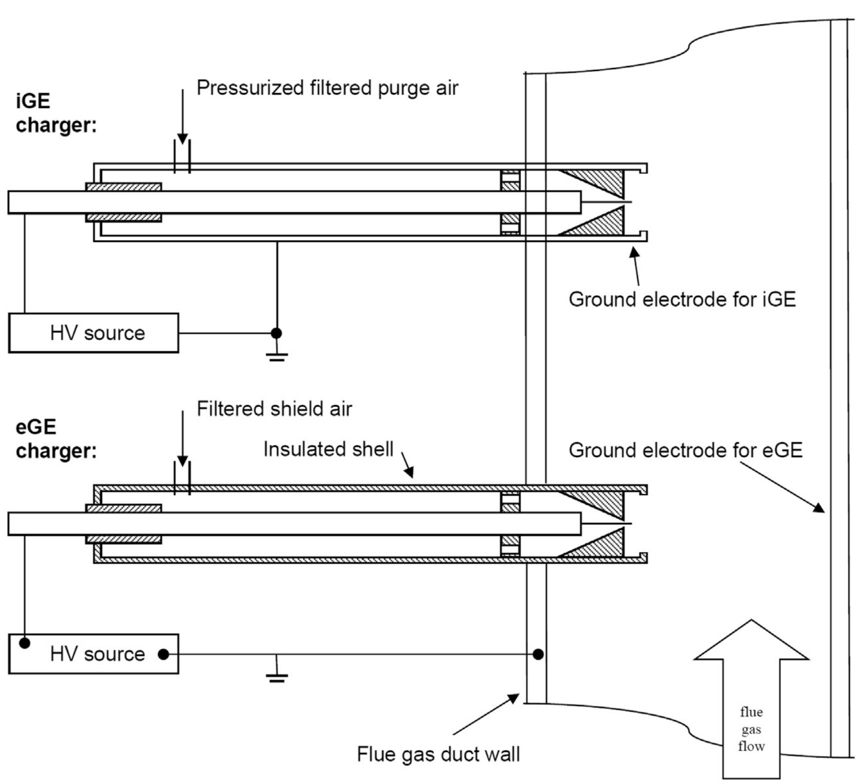

Fig. 1. A schematic diagram of the sonic jet-type chargers studied. In the iGE charger, the electric field is produced between the corona electrode and the charger body. In the eGE design, the corona field is produced between the corona electrode and the flue gas duct wall.