Performance of an electrostatic cyclone in removing of airborne particles and in decomposition of NOx

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Abstract One of the most serious problems nowadays is the environmental pollution. In air pollution some important measures have been established since decades, and the emission of some dusts and gases can be stopped by precipitators, such as cyclone, electrostatic precipitator, and others. Unfortunately the emission of airborne dusts causes environmental and health problems worldwide, therefore, to remove them is still an important issue. It is well known, that cyclones can remove dust successfully if the sizes of the particles are above 20-30 μm. The removal efficiency is greater if the gas speed is higher (up to a certain limit around 20 m/sec). The electrostatic precipitators are working satisfactorily if the average particle diameter is above 5-20 μm. The removal efficiency is decreasing by increasing gas speed. The optimal value is below 2 m/sec (rather 1 m/sec).

At the first extent the combination of the cyclone and the electrostatic precipitator seems to be senseless, but if we consider that the motion of the gas and the particle moving with that, in the tube of the outlet is still circular, and the gas will rotate around the internal perimeter of this tube more than 5-10 times, then we can realize that the particles move along this surface a long way providing enough time to the particle to be precipitated. Considering those facts, we built a cylindrical electrostatic precipitator into the outlet tube in order to remove airborne dust (d < 10 μm) from flue gases. Having a built in electrostatic precipitator in a cyclone, it is easy to use pulse energization for decomposition of NOx content of the flue gas introduced into the cyclone.

One of the new technologies is to produce SiC from industrial waste. The SiC is produced using plasma technology, and the end product of this step is powder with the diameter range of 10-70 μm in argon carrier gas. An electrostatic cyclone was constructed, built and applied successfully to collect these powders.

Keywords: Electrostatic Precipitator, Gas Cleaning, PM Removal, NOx Removal

1. Introduction

One of the most serious problems nowadays is the environmental pollution. In air pollution some important measures have been established since decades, and the emission of some dusts and gases can be stopped by precipitators, such as cyclone, electrostatic precipitator, and others. Unfortunately the emission of airborne dusts is causing environmental and health problems worldwide, therefore, to remove them is still an important issue.

It is well known, that cyclones can remove dust successfully if the sizes of the particles are above 20-30 μm. The removal efficiency is increasing by increasing gas speed, if it is below 15-20 m/sec.

The electrostatic precipitators are working well if the average particle diameter is above 5-20 μm. The removal efficiency is decreasing by increasing gas speed. The optimal value is below 2 m/sec (rather 1 m/sec). If the length of the electrostatic precipitator (ESP) is satisfactory, and the gas speed is low enough then the smaller diameter particles are also removable. Unfortunately the size of the equipment is too large, and the cost is too high in these latter cases.

At the first extent the combination of the cyclone and the electrostatic precipitator seems to be senseless, but if we consider that the motion of the gas and the particle moving with that, in the tube of the outlet (dip pipe) at the center of the cyclone is still circular, and the gas will turn around the internal perimeter of this tube more than 5-10 times, then we can realize that the particles move along this surface a long way therefore there are chances for the particles to be precipitated by electrostatic method, if they remained in the flue gas avoiding the precipitation in cyclone mode.

Considering those facts, we built a cylindrical electrostatic precipitator into the outlet tube in order to remove airborne dust (d < 10 μm) from flue gases.

When one is talking about precipitator, let it be any kinds of them, automatically thinks air or other flue gas containing some oxygen as the carrier gas.

Nowadays, however, there are technologies using other than air as carrier gas. In producing SiC powder treating industrial wastes by plasma, the final product is falling in the diameter range between 10 and 70 μm.

As the temperature of the exhaust gas is higher than 300°C, the only useful methods seemed to be the electrostatic cyclone.

In the literature a very few papers are dealing with cyclone and electrostatic precipitator combined in some sense. One of them is the Handbook of electrostatic ([1] Masuda, 1980). Papers dealing with removal of airborne dust by using combined cyclone and electrostatic precipitator did not appear to the authors of this paper, although rumors about those researches mentioning that there were some NOx removal technique described (in Filtration and Separation) by the researchers of University of Oita, led by Prof Ohkubo.

If the outlet tube of the cyclone is containing a discharge wire than instead of the usual DC energization a fast rising pulse can be supplied to it, therefore it is possible to remove also gaseous pollutants, NOx, freons or other chemicals.

In this paper the phenomena mentioned above is investigated and reported.

2. Materials and methods

In the present investigation a cylindrical electrostatic precipitator was built into a cyclone's outlet (dip) tube. The schematic drawing of the cyclone is shown in Fig. 1. The electrostatic precipitator was formed by the outlet (electrically earthed) metallic tube, and a center tungsten wire (with the diameter of 0.1 mm) and by a supporter at both ends of the tube. The supporters were made of Teflon according to the drawing of Fig. 2.

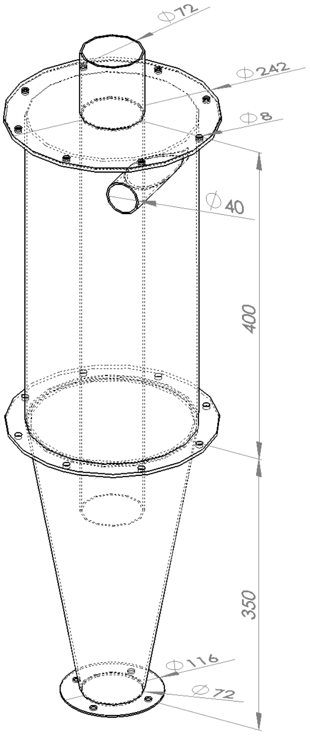

Figure 1. The cyclone used to build in the electrostatic precipitator into the dip tube

The center wire was spanned by a 10 mm long spring.

The photograph of the one end of the electrostatic precipitator can be seen in Fig. 3.

As the power supply for the electrostatic precipitator a variable DC power source was used. The voltage was changeable between 0 and 20 kV. The ripple of the DC was smaller than 2% at 1 A.

The flow rate of carrier gas was variable between 1 and 15 m/sec inlet speed. The feeding of the powder was controlled manually by using funnel. The average feeding rate was about 1 g/min.

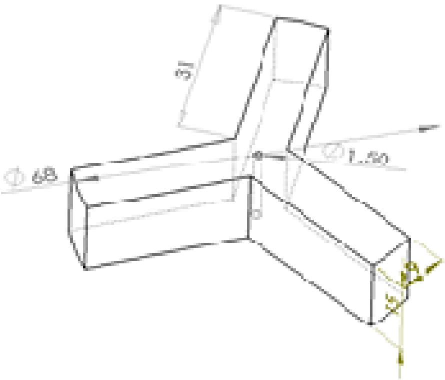

Figure 2. The supporters for the center wire

Figure 3. The photograph of one end of the electrostatic precipitation part of the cyclone

To remove SiC dusts from the flow of argon gas the electrostatic cyclone was used. In this case 8-9 kV of DC voltage was used, because higher voltage under that atmosphere caused breakdown in the precipitator tube. In some of this kind of experiments carbon dioxide was generated by the process at about 5% concentration, but this did not modify the precipitation processes.

In some of the flue gases NO contamination is measured between 5 and 600 ppm. In this experiment the NO was tried to be removed by fast rising pulse energization. The NO concentration was varied between 50 and 500 ppm in nitrogen atmosphere, and was fed simultaneously with carbon powder of 5 µm mean diameter.

The pulse power supply was operated according to Fig. 4.

The pulse wave form of current and voltage is given in Fig. 5.

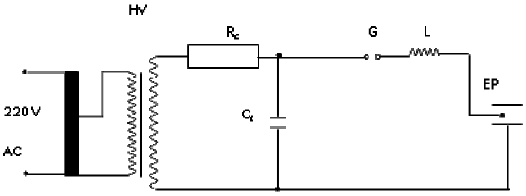

Figure 4. The schematic diagram of the pulse power supply

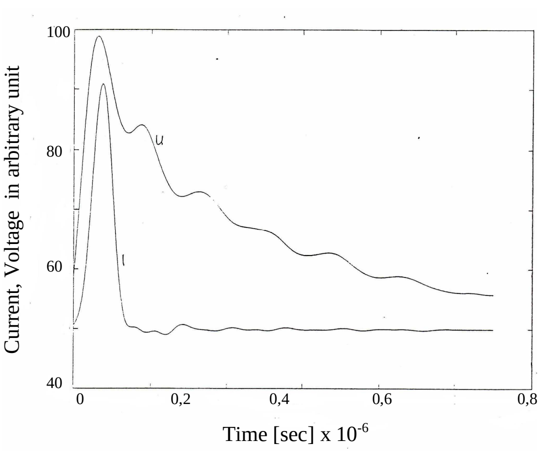

Figure 5. The waveform of the current and voltage in pulse energization (the voltages and the current values are in arbitrary unit)

The necessary NO-N_2 mixing is produced in an experimental arrangement indicated in Fig. 6.

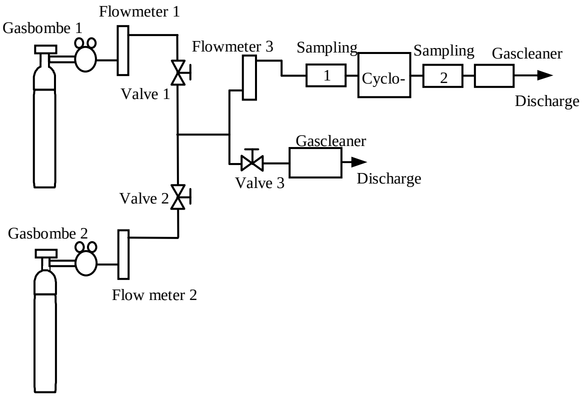

Figure 6. The experimental arrangement to mix NO and N_2 in order to get the necessary mix

The dust concentration was determined by filter-gravimetry methods, the NO concentration was determined by a Beckman Industrial 951A NO/NOx analyzer.

The powders used were: carbon powder collected by bag filter of an industrial process, with the main diameter of 5 µm with the half tail of 6 µm; grind powder with the main diameter of 50 µm, half tail of 70 µm; alumina powder with 7 µm mean and 6 µm half tail; a plaster powder with 10 µm mean and 20 µm half tail; and SiC powder with 25 µm mean diameter at 10 µm half tail.

3. Results

Generally speaking it has been found that the penetration (the unremoved fraction of the dust) for the airborne particles (d < 10 µm) in the case of working built in electrostatic precipitator, decreased to 5-10% of the penetration of the (only) mechanical cyclone operation. The penetration data is given at various dusts and voltages. All are proving that the method is working satisfactorily. If the voltage was smaller than the on-set voltage of the discharge, the better performance was also observed meaning that with electric field it is possible to utilize the tribo-charge of the dust particles caused by the collision with the wall of the cyclone.

In carbon filter powder with the mean diameter of 5 µm a very detailed efficiency measurement has been conducted.

The precipitation efficiency without electrostatic extension is rather low at lower flow velocities, and at low applied voltages, but above 7 m/sec is rather acceptable. There is an abrupt change between 0 and 5 kV applied voltage in the efficiency. The corona onset voltage is around 7 kV. Above 9 kV the efficiency is changing again Fig. 7 and Fig. 8.

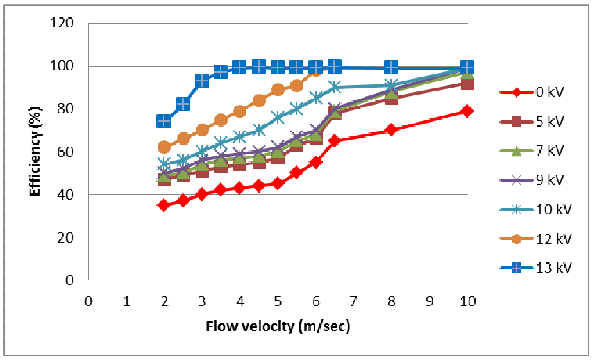

Figure 7. The efficiencies of the electrostatic cyclone in the case of carbon filter powder (main diameter of 5 µm) at different flow velocities with the applied voltages as parameters

In the case of ordinary very fine (mean diameter of 10 m) plaster material used in building industries the applied inlet flow velocity was 6 m/sec, and the efficiency of the mechanical cyclone was about 96,5%, but the switched on electrostatic precipitator improved the precipitation as it can be seen in Fig. 8.

Similar results were obtained for the other above mentioned materials. The results are already given in [2].

Simultaneous removal of 50 ppm NO and carbon filter powder resulted the curves shown in Fig. 10.

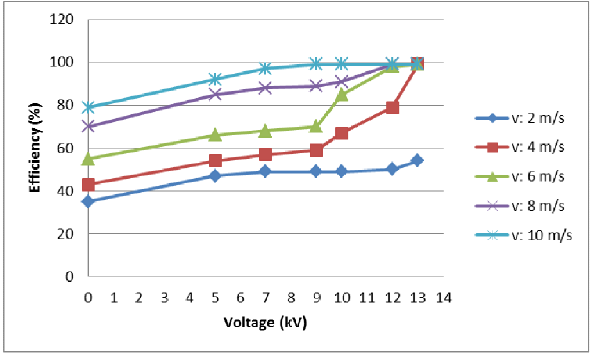

Figure 8. The efficiencies of the electrostatic cyclone in the case of carbon filter powder (main diameter of 5 µm) at different flow applied voltages with the flow velocities as parameters

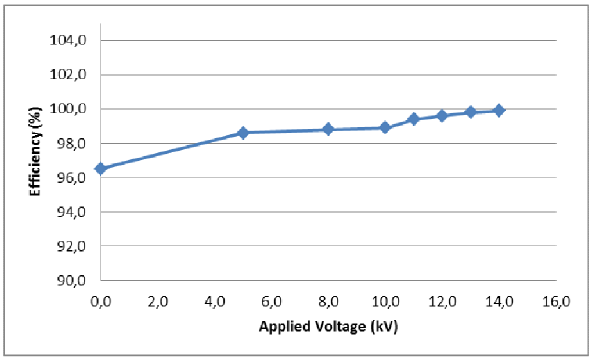

Figure 9. The precipitation efficiency vs. Applied voltage in the case of ordinary very fine (mean diameter of 10 m) plaster material used in building industries, the applied inlet flow velocity is 6 m/sec

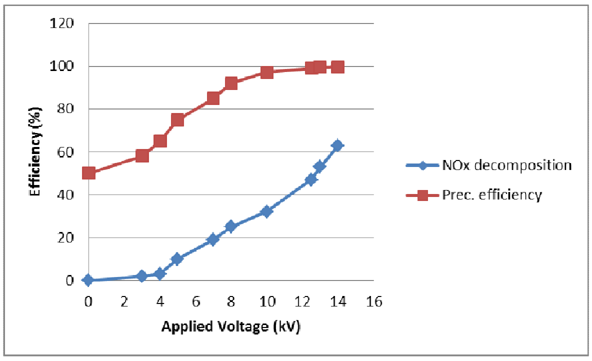

Figure 10. The decomposition of 50 ppm NOx in nitrogen carrier gas and the precipitation efficiency of the carbon filter powder using the electrostatic cyclone

The decomposition of SiC powder under argon atmosphere can be also made. The dependence of the precipitation efficiency on the applied voltage is given in Fig. 11. The mean diameter of the powder was 50 µm, the load was 1 kg/h, the dust concentration was 0.83 g/l.

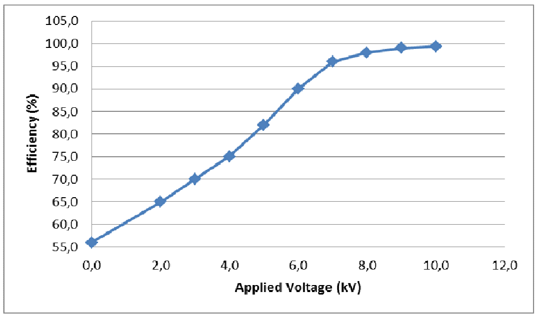

Figure 11. The precipitation efficiency of SiC powder under argon atmosphere

4. Conclusion

The cyclone itself (without electrostatic field) has efficiency above 90% for most of the powders investigated. The efficiency was increasing by increasing air speed.

If the DC high voltage power supply was switched on, the efficiency increased, and the penetration decreased for all of the tested dusts.

It is very much important to mention that the penetration at 0 kV was a certain value, which decreases substantially even below the corona onset (which is about 7-8 kV at this geometrical arrangement) if the voltage is on. It means that the particles have own electric charges when they enter into the ESP. This charge can be a tribo-charge caused by the collision of the particle with the wall of the cyclone.

In foundry industry graphite powder is used rather often, and by the end of the casting process it is blown out from the factory into the environment. Before discharging the exhaust gas, it is filtered, but the filtering out of these fine particles is rather a difficult task. Cyclone itself can not solve the problem, but by combination with ESP we can keep the environment by removing the ultrafine particles, at least the experimental results are indicating. The penetration of the graphite powder with the mean diameter of 8 µm is below 0.3% if the ESP's DC high voltage is high.

The device can be used effectively in removing SiC particle in argon atmosphere even at higher temperature.

In the case of pulse energization of the ESP the NOx content of the gas could be decomposed with 60-70% efficiency.

References

[1] Masuda S., *Handbook of electrostatics*. OMU, Tokyo, Japan, 1980.

[2] Kiss E., *Int. Rev. of Appl. Sci. and Engineering*, Akademiai Kiadó, Vol. 2, No 2, (2011) pp 107-110.