We developed a novel ESP with a thin water film on collection plates consuming an extremely low water of 1.5 L/min/m$^2$. A wet ESP (400 m$^3$/h) was tested with flue gas from a 0.7 MW Oxy-PC boiler. We measured particle removal efficiency of the wet ESP, changing inlet particle concentration and applied voltage using gravimetric method and optical particle counter with a dilution system, and also evaluated SOx removal efficiency based on the EPA method 8. The collection efficiency of the wet ESP increased linearly as the power consumption for the ESP increased, and highest efficiency was over 90% even for the ultrafine particles. In addition, the wet ESP removed SO$_2$ and SO$_3$ by 64.5% and 23.1% only with thin water film on the collection plates because the ESP might remove mists which contained SO$_2$ and SO$_3$ which were generated by heterogeneous nucleation and condensation of water vapor in the wet ESP. With these results, the novel wet ESP with a thin water film on the collection plates which cleans the collection plates continuously could be a possible solution for new combustion technology which needs extremely high removal performance of pollutants.

Keywords: Oxy-PC, Particle, electrostatic precipitor, wet, water consumption

1. Introduction

Several researches on dry ESPs for oxy-fuel combustion have been conducted, but Han et al. (2010) and Suriyawong et al. (2008) focused on removal performance with a lab scale ESP and submicron particles which were not representative of particles from industrial combustion plants, and Bäck et al. (2011) studied on a 30 MW-scale oxy-fuel combustion with only a dry ESP system, and did not deal with the performance comparison of the wet ESP for different combustion conditions such as air and oxygen-firing combustion with in-furnace deSOx. In this study, we developed a novel wet type ESP and combined with the conventional dry ESP to remove particles from oxy-PC combustion near to 1 mg/m$^3$. Also, we investigated on changes of performance of the ESPs by changing combustion conditions and operation parameters of the ESP using a 0.7 MW oxy-PC combustion pilot plant.

2. Experimental set up

We used a 0.7 MW-Oxy PC pilot plant for CCS in this study. The pilot plant was constructed at a site in Korea Electric Power Research Institute (KEPRI), Daejeon, Korea. The plant was composed of a 0.7 MW-Oxy-PC boiler.
with in-furnace desulfurization unit, air separation unit (ASU), gas cleaning system composed of a dry ESP, Flue gas condenser (FGC) and wet ESP with water films, and CPU. Differently from the conventional desulphurization for coal combustion power plants, in-furnace desulfurization method which spays limestone directly into the boiler was applied in this study. The one-field ESP with six collection plates of a SCA of 60 m²/1000 m³/h was used to remove a majority of the particulates in a flue gas of 200-230°C from the boiler. The heat exchanger and Flue gas condenser (FGC) were used to remove water content by decreasing temperature to 40°C. In particular, the FGC was worked by wet-scrubbing using water with pH 7 to remove SOx in the flue gas to CPU. In order to remove ultrafine particles which are hardly removed by the conventional dry ESP, one field wet ESP with four collection plates of a SCA of 2.3 m²/400 m³/h which had a thin water film on the surface of the collection plates was applied to this study. Due to the surface treatment with nanometer particle coating and sand blasting on the collection plates, the water consumption was only 1.5 L/min/m² which was the much lower than the water consumption for a wet ESP (Kim et al., 2011). High power suppliers with maximum 70 kV/ 400 mA for the dry ESP and 60 kV/ 40 mA for the wet ESP were provided from the NWL Pacific Inc.

The gravimetric measurements (EPA method 5 for particles and method 8 for SOx) were conducted and also particle measurements were with optical particle counters (Model 1.109, Grimm, Germany) with an ejector type dilutor (1:1000, DEED, Dekati, Finland) to minimize effect of water vapor on the measurements. The particle removal performance of the ESPs in this study was expressed by the particle collection efficiency (η) which can be obtained by the following equation,

\[ \eta = \left(1 - \frac{C_{\text{down}}}{C_{\text{up}}} \right) \times 100 \]  \hspace{1cm} (1)

where η is the collection efficiency, C_{\text{down}} and C_{\text{up}} the particle mass concentration of downstream and upstream of the ESPs.

3. Results and Discussion

Figure 1 shows the particle mass concentrations before and after the wet ESP. The particles flowing into the wet ESP were smaller than 1 μm, and the mode size at which the most concentration was observed was approximately 0.4~0.5 μm. The concentration for entire particles was dramatically decreased as 67 kV/ 3mA was applied to the wet ESP.

Figure 2 shows the collection efficiency as a function of power consumption of the wet ESP. As the power consumption was over 100 W, the collection efficiency with the dry EP ON and even with OFF was higher than 90% which means that the wet ESP could remove high concentration particles when the dry ESP works inefficiently.

Figure 3 showed the SOx removal efficiency of the wet ESP. Even though the wet ESP does not have any function to remove gas phase pollutants, it removed SO2 and SO3 by 66% and 23%, respectively. This is attributable to the fact that the wet ESP removed mists which consume the gases in the Flue Gas Condenser and the wet ESP.

Due to the additional reduction of the small particles in the wet ESP, the average gravimetric concentrations downstream of the wet ESP for oxygen firing combustion was 1.9 mg/m³, while those upstream and downstream of the dry ESP were 11.72 g/m³ and 17.2 mg/m³.

4. Conclusion

We achieved final average particle emission from the oxy-PC combustion of 1.9 mg/m³ by the additional operation of a wet ESP with thin water films on collection plates using only 1.5 L/min/m² of water.

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6. Reference

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Figure 1. Changes in size distributions before and after the wet ESP

Figure 2. Changes in collection efficiency as a function of power consumption

Figure 3. SOx removal efficiency of the wet ESP