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Effects of phosphoric acid sprayed into an incinerator furnace on the flue gas pressure drop at fabric filters

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ABSTRACT

Fabric filters are widely used to remove dust from flue gas generated by waste incineration. However, a pressure drop occurs at the filters, caused by growth of a dust layer on the filter fabric despite regular cleaning by pulsed-jet air. The pressure drop at the fabric filters leads to energy consumption at induced draft fan to keep the incinerator on negative pressure, so that its proper control is important to operate incineration facility efficiently. The pressure drop at fabric filters decreased whenever phosphoric acid wastewater (PAW) was sprayed into an incinerator for treating industrial waste. Operational data obtained from the incineration facility were analyzed to determine the short- and long-term effects of PAW spraying on the pressure drop. For the short-term effect, it was confirmed that the pressure drop at the fabric filters always decreased to 0.3–1.2 kPa within about 5 h after spraying PAW. This effect was expected to be obtained by about one third of present PAW spraying amount. However, from the long-term perspective, the pressure drop showed an increase in the periods of PAW spraying compared with periods for which PAW spraying was not performed. The pressure drop increase was particularly noticeable after the initial PAW spraying, regardless of the age and type of fabric filters used. These results suggest that present PAW spraying causes a temporary pressure drop reduction, leading to short-term energy consumption savings; however, it also causes an increase of the pressure drop over the long-term, degrading the overall operating conditions. Thus, appropriate PAW spraying conditions are needed to make effective use of PAW to reduce the pressure drop at fabric filters from a short- and long-term point of view.

1. Introduction

Fabric filters are widely used in dust collection equipment for flue gas discharged from solid waste incinerators because they remove particulate matter with high efficiency. Over time, a dust layer builds up on the fabrics, which increases the particulate matter removal efficiency; however, it also causes an increase in the pressure drop at the fabric filters. The pressure drop increases in three steps: dust builds up inside the fabric filter; a dust layer forms on the surface of the filter; and the dust layer grows thicker (Calle et al., 2002). For a high-pressure drop at the filters, the induced draft fan (IDF) consumes more electricity to keep the incinerator on negative pressure. The pressure drop at the fabric filter is said to account for approximately 60% of the total pressure drop in the flue gas treatment system. Therefore, controlling the pressure drop at the fabric filter is important for reducing energy consumption of flue gas treatment systems, and for increasing the net efficiency of energy recovery at incineration facilities.

Previously considered approaches to reduce the pressure drop in fabric filter include controlling the filtration velocity and dust concentration and changing the filter materials. Song et al. (2006), Chen and Hsiau (2009), and Saleem et al. (2012) have reported that the filtration velocity influences the increase of the pressure drop more than the dust load, dust concentration, and the dust layer thickness. Pulsed-jet air to detach dust on the fabric filter surface is a commonly used method to clean the filter and decrease the pressure drop. According to Ellenbecker and Leith (1983) and Saleem et al. (2011), the amount of dust that is dislodged by pulsed-jet air cleaning varies depending on the filter material. They notes that dust can be most effectively cleaned from PTFE-based filters. Iinoya et al. (1979) reported that the rate of dust removal by pulsed-jet air cleaning stabilizes after repeated cleaning. However, Siever and Löffler (1989) and Ikeno et al. (2004) reported that dust on filters was not uniformly dislodged from the filter surfaces. Dust was partially cleaned, with a dust layer remaining over parts of the filter surface.

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This study is motivated by a phenomenon that has been reported at an industrial waste incineration plant, where the pressure drop at a baghouse decreased when phosphoric acid wastewater (PAW) was sprayed into the incinerator. The pressure drop decrease was also observed when pure phosphoric acid solution was sprayed, suggesting that the phosphoric acid in PAW was responsible for reducing the pressure drop (Takahashi et al., 2015). Takahashi et al. (2015) reported that the power consumption of IDF decreased simultaneously with the decrease of pressure drop at the baghouse during PAW spraying tests. Particle size distribution of dust discharged from the baghouse by pulse-jet cleaning before and during PAW spraying was measured in the same tests. Median diameter (D_{50}) and a weight fraction of large size of particle (>100 μm) increased during PAW spraying, implying that agglomeration of dust particles by PAW sprayed to incinerator might lead to the pressure drop decrease at the baghouse. Based on the thermodynamic equilibration calculation, phosphoric acid sprayed to incinerator formed Ca-P compounds, e.g. hydroxyapatite ($Ca_5(PO_4)_3OH$), at 185 °C of fabric filter by reacting with $Ca(OH)_2$ sprayed to the duct for acid gas scrubbing (Mukaiyama et al., 2014). Phosphoric acid was known as a chemical to suppress the leaching of heavy metals from fly ash (Uchida et al., 1996; Kim et al., 2003; Buj et al., 2010), which is considered as one of merits obtained by PAW spraying.

To use PAW as a reagent for reducing the pressure drop of baghouse, it is necessary to confirm the reproducibility of the effect and the quantitative relationship between the pressure drop decrease and PAW spraying conditions. Furthermore, it should be determined how long the effects of pressure drop reduction might last after PAW spraying. This study aims to clarify the effects of PAW spraying on the pressure drop of a baghouse through short- and long-term analyses of operation and by monitoring data obtained from an industrial waste incineration plant.

2. Outline of surveyed industrial waste incineration facility

The industrial waste incineration facility surveyed in this work started operating in August 2009. The amount of waste treated daily is almost constant, around 87.9 tons/d in average, and comprises 55% paper and plastic, 22% sludge, 22% wastewater including waste acid and alkali solutions, and 1% infectious waste, on a wet weight basis.

Fig. 1 shows the process flow of the industrial waste incineration plant. Incineration is performed in a moving grate or a rotary kiln depending on the waste type. Flue gas is cooled by heat recovery at a boiler and water quenching, and is then neutralized by slaked lime. Dust is primarily collected at the first baghouse (BH1). Slacked lime and activated carbon are then blown into flue gas that has passed through BH1, which then passes to the second baghouse (BH2). Each bagbouse is equipped with 378 PTFE-fabric filter bags (9 bags/row × 42 rows). Each row is cleaned by pulsed-jet air applied at 150 s intervals. The interval of cleaning automatically is adjusted to 30 s if the pressure drop of BH1 becomes higher than 1.5 kPa. An IDF is located at the outlet of BH2, and its rotation speed is automatically controlled to maintain a negative pressure on the incineration chamber. The treated flue gas is then discharged from a stack.

Incineration of PAW started from April 2011. The PAW was alkaline wastewater neutralized with phosphoric acid, which was discharged from an electronic device factory. Approximately 9700 ± 300 kg of PAW was delivered to the facility every month, mixed with water or other wastewater, and stored in a tank. Table 1 shows the characteristics of PAWs sampled before storing in a tank. Concentrations of total carbon, nitrogen, and phosphorus were almost same between PAWS carried in different dates. Heavy metal concentrations were also measured but were low or less than detection limits.

The surveyed period was divided into four sections based on the periods over which PAW spraying occurred and the replacement of the fabric filters (Table 2). Section A is a reference period, during which no PAW spraying occurred. PAW spraying occurred during Section B, C, and D, and the fabric filters were changed between each of these sections. The replacement filters were also made of PTFE; however, these were manufactured by different makers.

In this work, the short- and long-term effects of PAW spraying on the pressure drop of BH1 were investigated. The short-term effects of PAW spraying were defined as the influences on the pressure drop occurring during the period when PAW was sprayed into the incinerator. Individual PAW-spraying periods were denoted as runs. The long-term effects of PAW spraying on the pressure drop were also investigated over the whole operation period, which was subdivided into blocks. Monitoring data, e.g. pressure differences between the inlet and outlet for BH1 and BH2, flue gas flow rate, and absolute pressure at each stage of the incineration process, were obtained from surveyed industrial waste incineration facility. Data measured at 1 h intervals were used in this study. Pressure drop at BH1 and flue gas flow rate were denoted as ΔP and Q, respectively. Additionally, the concentration of phosphoric acid in PAW, the amount of PAW sprayed, the duration of PAW spraying, and the amount of treated solid waste were included in the analysis. As the pressure drop at BH2 was small, it was not analyzed.

3. Short-term effects of PAW spraying

Fig. 2 shows one case of a decrease in ΔP during PAW spraying. As soon as PAW was sprayed into the incinerator, ΔP started to decrease. The values of ΔP at the start and end of PAW spraying were denoted as ΔP_i and ΔP_f, respectively. The minimum value of ΔP during PAW spraying was $\Delta P_{\min}$. Using these values, the total pressure drop reduction that occurred during PAW spraying was determined from the difference between ΔP_i and $\Delta P_{\min}$ ($\Delta P_i - \Delta P_{\min}$). The duration of PAW spraying (t_s) and the time taken to the minimal pressure drop ($t_{\min}$) were also determined. In addition, the recovery time (t_r) was defined as the time taken for ΔP to increase and stabilize again after ending the PAW spraying. The gas flow rates at the start and end of the PAW spraying were Q_i

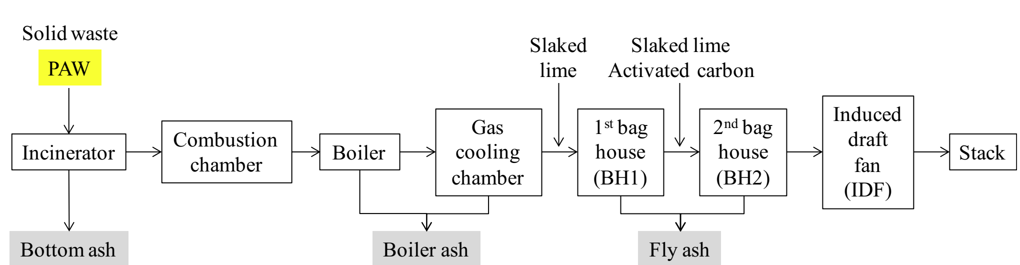

Fig. 1. Process flow diagram of the facility.