

Experimental investigation of optimum blend ratio of deodorant powder for removal of TVOCs from a foundry plant

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Abstract:

Foundry is an important industrial process for making metal products in desired shapes especially for complex models that might not be economical to manufacture by other methods. However, the process also generates vast amounts and various types of air pollutants such as odor-causing volatile organic compounds (e.g., hydrogen sulfide, ammonia, etc.) and particulate matters. Therefore, development of technique that can efficiently eliminate these emissions released from the process is regarded as an essential research. For the purpose to simulate an existing pollution control system, in this study, a spray adsorption system was designed to work with a bag filter so as to remove total volatile organic compounds (TVOCs) and dust particles simultaneously actually emitted from the de-molding process of a foundry plant. Maximization of process efficiency, by finding optimum blend ratio of deodorant powders selected i.e. activated carbon (AC) and zeolite (ZL), was the focus of this research. Seven mixing ratios of AC and ZL were tested in several conditions. Through the experiments, TVOCs removal efficiency of more than 95% for all conditions was obtained from the adsorbent that composed of 80% AC (800 mesh) and 20% ZL (300 mesh) by mass.

Keywords: Activated carbon; Adsorption system; Bag filter; Foundry; Odor removal; Zeolite

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1. Introduction

Foundry manufacturer is an industry that makes casting products by using many grades and types of metals, including pig iron and scrap iron transferred from industrial activities, as raw materials. For the manufacturing processes, raw metal materials are melted in a foundry furnace and poured into a mold. The solidified metal pieces are then removed from the mold. Grinding and machining are the last major steps to get rid of excess components and form finished products (Kang, 2007). Although the foundry manufacturer has an important role in supplying metal products in shape that meet customers' need, it can be recognized as 3D (dirty, difficult, dangerous) industry. This is because a tremendous amount of air pollution – especially smelly gases and dust particles less than 10 microns in diameter (PM10) – is released from the processes (Park and Im, 2007). In Changwon city, South Korea, the city council has received many complaints about odors coming from a variety of sources (CCH, 2014). Odor complaints have been frequently attributed to foundry manufacturers. Occurrence of volatile organic compounds (VOCs), including 22 malodor components designated as the major odorants under the Korean regulation, is detectable from the foundry process due to the usage of organic compounds as additives in the production process (KMOE, 2008; KOSORE, 2010). Enhancement of emission control capable of removing TVOCs more efficiently is, therefore, an important and urgent task of the city council according to its commitment to improve air quality to reach the regulatory standards by 2015 (CCH, 2014).

In order to remove gaseous odorant, adsorption is one of the methods that are extensively utilized. Adsorption is a phenomenon occurring from the interaction between adsorbate and adsorbent surface. The exact nature of the bonding and adsorption capacity depend on component species involved. Hence, efficiency of each adsorbent to capture individual/mixed gas(es) is not equal and the gap of performance is significant (Burgess et al., 2004; Jung et al., 2008; Masuda et al., 1999; Rajbansi et al., 2014). Nevertheless, the usage of spray adsorption system with a single deodorant is being implemented in many factories located in this industrial area according to the results obtained

by personal interviews. One type of efficient deodorant might not be able to control all kinds of odor compounds (Masuda et al., 1999).

Activated carbon (AC), carbon-based compounds, is a well known adsorbent that can be used efficiently for elimination of pollutants from air. However, ammonia, a major odor-causing gas released from casting plant, could not be efficiently removed by AC. Zeolite (ZL), oxygen-containing compounds, which has superior performance than AC on removal of ammonia (Masuda et al., 1999; Rajbansi et al., 2014) is an interesting solution to complement AC. A combination of AC and ZL to cope with the odor problems was also recommended by a factory that allowed installing a pilot-scale experimental study with a quantity of air pollutants actually emitted from the process. Therefore, the aim of this study is to increase the capture capacity of spray adsorption system for removal of TVOCs by finding the best possible blend ratio of commercial deodorant powders selected i.e. AC and ZL.

2. Material and methods

In order to set up the environment of experiment as similar as the real situation, the pollution control system was installed inside a foundry plant in Changwon city, Korea. An amount of air pollutants emitted from a working place was directly supplied to the treatment system comprising a baghouse dust collector and a spray adsorption system to remove dust and TVOCs at the same time.

2.1 Experimental devices and components

The entire system can be divided into three main parts i.e. air blower, bag filter, and adsorbent spray device as shown in Fig. 1. The actual devices at installed point are presented in Fig. 1 (a) and each sub-unit of the system is illustrated in Fig. 1 (b). The deodorant supplier and deodorant spray equipment are installed in front of the rectangular bag filter dust collector. The air blower is used in conjunction with the bag filter. The experimental specification is set as shown in Table 1. Conditions in Table 1 that could be the cause of turbulent flow had been adjusted repeatedly. The smaller a size of adsorbent, the larger the surface area is, resulting in the higher capacity for adsorption (Kara et al., 2007). Accordingly, two sizes of AC (400 and 800 mesh) are applied to find the efficiency gap of particle size. Supply of deodorant can be altered and fixed by DC thyristor variable motor and the volume of spray owing to the variation of power is presented in Table 2.

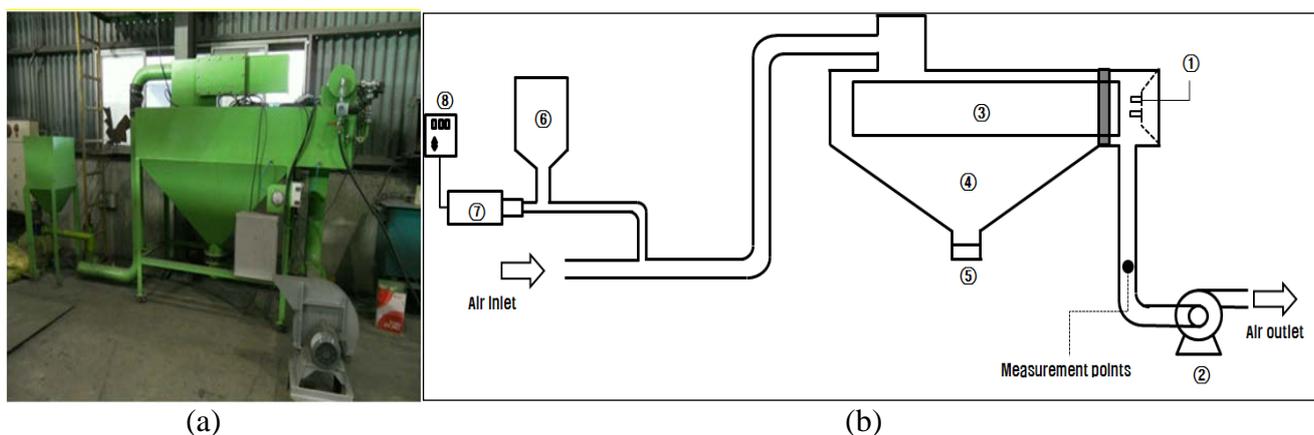


Fig. 1 (a) Emission control devices (b) Schematic diagram of experimental system:
(1) Jet nozzle, (2) Air blower, (3) Bag filter, (4) Bag house,
(5) Hopper valve, (6) Adsorbent inlet, (7) DC thyristor variable motor, (8) Speed controller.

Table 1 Experimental specification

Division	Value	Division	Value
Flow rate through bag house*	10 CMM	Differential pressure of bag house*	120 mmAq
Pulse pressure*	3 kgf	Pulse time*	0.1 second
Pulse interval*	20 second	Power for supply of deodorant	10, 20, 30, 40 and 50 Hz
Activated carbon	400 and 800 mesh	Zeolite	300 mesh

* Controlled variable

Table 2 Measurement results

TVOC measurement results (ppm)							
Formation	Blend ratio	Deodorant supply (kg/m ³)					
		0 (0Hz)	0.18 (10Hz)	0.43 (20Hz)	0.6 (30Hz)	1.09 (40Hz)	1.3 (50Hz)
400 mesh AC + 300 mesh ZL	Case 1 (100% AC + 0% ZL)	870	320	40	25	18	15
	Case 2 (80% AC + 20% ZL)	870	150	38	20	19	17
	Case 3 (70% AC + 30% ZL)	870	180	150	90	78	30
800 mesh AC + 300 mesh ZL	Case 4 (100% AC + 0% ZL)	870	100	65	50	45	40
	Case 5 (80% AC + 20% ZL)	870	45	30	27	25	25
300 mesh ZL	Case 6 (70% AC + 30% ZL)	870	145	50	35	30	30
	Case 7 (0% AC + 100% ZL)	870	840	310	250	230	200

2.2 TVOCs concentration and case studies' condition

Permission to conduct the experiment in the study site was granted as necessary. Quantity of TVOCs usually emitted from de-molding process, an area permitted for doing research in the factory, is significant (KOSORE, 2010; Park and Im, 2007). To measure TVOCs concentration for this analysis, TVOC Meter (UltraRAE 3000) was exercised every one hour for 10 times. Without any emission control system, the average of the measured values was 870 ppm as shown in Fig. 2 and it was assumed as the emission rate for the entire time of experiment. Thirty-five conditions of the test, made up by three formations of mixing, seven cases of blend ratio, and five levels of deodorant amount, are presented in Table 2 together with the results of the experiment.

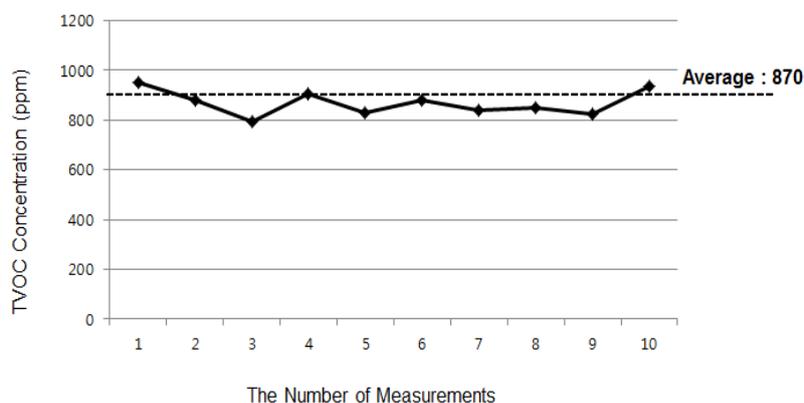


Fig. 2 TVOCs concentration from de-molding process.

3. Results and discussion

Surprisingly, the most efficient ratio is case 1, pure AC at the highest amount of deodorant supply (50Hz: deodorant volume ~1.3 kg/m³) with the bigger size of AC (400 mesh), as shown in Table 2. However, from the overall perspective, the efficiency of 800 mesh AC is better than 1.6 times that of 400 mesh AC (by considering from average results of case 1-3 and 4-6), consistent with the theory about adsorbent's size. As well, from the average values of all cases, 20% ZL and 80% AC by mass is distinctly the best blend ratio if compared to all other cases. The worst performance is the case 7 that ZL is applied alone without AC. Case 1 at 50Hz of power supply is suggested at the current stage because the efficiency of malodor removal is the major priority of this investigation.

4. Conclusion

It can be found from this study that the blend ratio of deodorant powders is significant for the change of efficiency of pollution control system. However, the obvious trend of relationship between the change of ratio and the capture capacity is still unrevealed. As well, an economic investigation is necessary to clearly address the appropriate blend ratio in term of cost. Further research should be directed towards focusing more number of repetition as well as broader ranges of volumetric flow, blend ratio, and size of deodorant. For the comprehensive analysis, dust particles should be also measured in the same time for all conditions of experiment not only at the de-molding process but all possible sources of emissions of the foundry plant.

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