Deodorization System Development by using Positive Pulsed Corona Discharge

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1 Abstract:

Pilot deodorization system experiment by using plate-rod positive pulsed corona discharge had been performed to evaluate removal efficiency for waste food dry recycling plant flue gas and to attest scale-up ability. As result of analysis of flue gas material composition at inlet and outlet, about over 50% odor materials are converted to non-odor molecular at electrical potential difference of about over DC 30kV and DC with pulse 42kV on positive pulsed corona discharge

2 Introduction

Over the last decades, compact dielectric barrier discharge (DBD) type deodorization systems have been developed [1-3]. But it is generally too small to apply for plant size because of DBD fluid dynamic problem between electrodes [3-4]. Another non-thermal plasma system for deodorization method, plate-rod type positive pulsed corona discharge electrode system has merits to make plant size facility as compared to DBD type.
Therefore, plate-rod type positive pulsed corona discharge method has been applied to our deodorization system to remove odor materials in flue gas which are production of a waste food dry recycling plant.

2.1 PILOT SYSTEM DESIGN

2.1.1 Basic Design Criteria

Gas volume flow rate and gas composition are very important criteria to design deodorization system. We designed non-thermal positive corona reactor base on 2000 Nm3/hr gas volume flow rate and to crack odor molecular structure, high electric filed strength has been adopted as 7.5kV/cm discharge on dc only and 15kV/cm discharge on dc with pulse

Plasma reactor has three major parameters. Firstly, gas residence time is most important parameter to remove odor molecular as a view of chemical side. Secondly, power source capacitance is significant parameter to transfer energy from DC transformer to plasma reactor discharge field as a view of electrical side. Thirdly, system inlet gas distribution ducts sizing and anticorrosion material selection are as a view of mechanical side. Summarized parameters are shown as table 1.

TABLE 1: BASIC DESIGN PARAMETERS OF PILOT SYSTEM

GAS Flow Rate	2000 Nm3/hr	
Capacitance	13.3 nF	
AC Source Power	3 Phase, 440V, 52.4A	
DC TR Power (Fig 1)	DC 30kVA, Pulse 20kVA	
Odor Material	Mercaptan and 16 other materials	
Electric Field Strength	DC : 7.5kV/cm DC+Pulse : 15kV/cm (50Hz)	
Plasma Reactor (Fig 1)	Height	2.0 m
	Length	2.1 m
	Width	1.6 m
	Gas Residence time	5 sec
	Material	SUS-316L

2.1.2 Plasma Reactor Inlet Gas Composition

Composition	Plasma Reactor Inlet Density [ppm]
Ammonia	78
Methyl mercaptan	2.298
Hydrogen sulfide	35
Dimethyl sulfide	0.068
Dimethyl disulfide	0.049
Acetaldehyde	0.01
Styrene	0.041
Propionaldehyde	0.006
n-Butyraldehyde	0.005
n-Valeraldehyde	0.022
i-Valeraldehyde	0.01
Toluene	0.017
Xylene	0.365
Methyl ethyl ketone	0.054
Methyl isobutyl ketone	1.828
Butyl acetate	0.013
Propionic acid	0.021
TOTAL	117.807

TABLE 2: ODOR MATERIAL DENSITY DISTRIBUTION AT PILOT SYSTEM INLET

As average result of inlet gas composition analysis, plasma reactor inlet odor material composition is shown as table 2. Density of ammonia is about 60% of odor material composition, density of hydrogen sulfide is about 30% of odor material composition and 2% of odor material composition is methyl mercaptan.

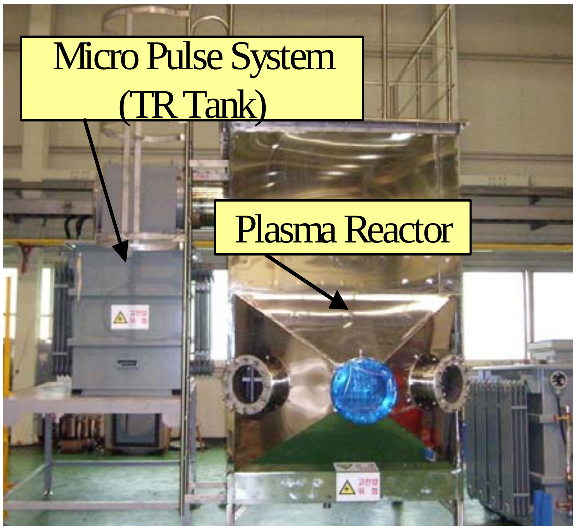

Fig. 1: Assembled pilot system which has two parts: Left (Micro Pulse System), Right (Plasma Reactor)

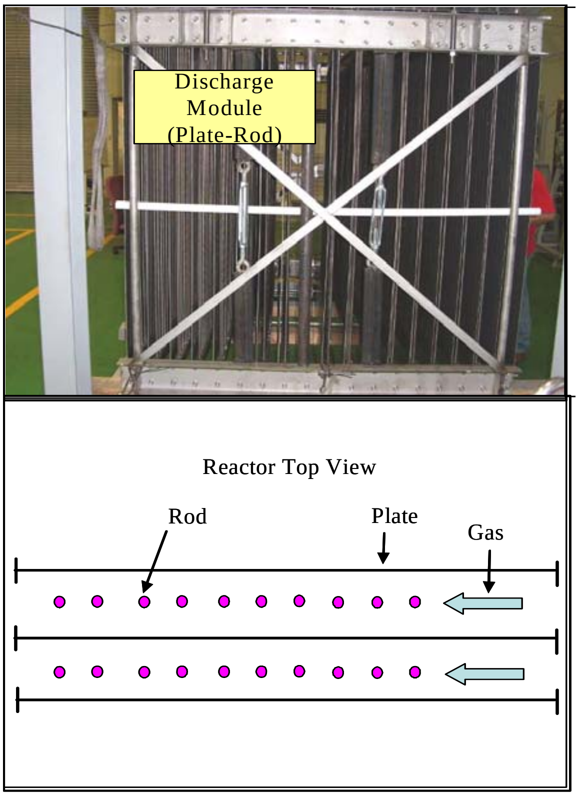

Fig. 2: Up (Plate-rod type discharging module) Down (Reactor top view)

2.1.3 Discharge System Design

Discharge module (Fig 2) is located in plasma reactor inside which has plate and rod structure. Plate side is charged as negative pole (cathode) and rod side is charged as positive pole (anode).

$$W = \frac{1}{2} C_r V^2 \qquad (1)$$

$$P = IV_{dc} + IV_{pulse} \quad (2)$$

We can calculate total transferred energy from electrical source to inside of plate-rod structure by using equation 1 [5]. Cr is capacitance of plate-rod module and V is charged potential difference between plate and rod. Therefore, we derived maximum plate-rod module capacitance to find maximum energy transfer point by changing geometry of plate-rod [6]. To evaluate pulsed energy transfer efficiency, Equation 2 had been used by comparing with Equation 1 after checking system current and voltage.

3 Application and Result

3.1 Application: Waste Food Dry Recycling Plant

Developed pilot system shown in Fig 3 has been tested for 3 months to remove odor in flue gas which are production of a waste food dry recycling plant.

Fig. 3: Pilot system was installed for flue gas odor treatment test at waste food dry recycling plant

3.2 Result

TABLE 3: ODOR MATERIAL DENSITY DISTRIBUTION AT PILOT SYSTEM OUTLET AND REMOVAL EFFICIENCY

Composition	Removal Efficiency [%]
Ammonia	46%
Methyl mercaptan	100%
Hydrogen sulfide	84%
Dimethyl sulfide	100%
Dimethyl disulfide	82%
Acetaldehyde	~100%
Styrene	~100%
Propionaldehyde	~100%
n-Butyraldehyde	~100%
n-Valeraldehyde	~100%
i-Valeraldehyde	0%
Toluene	~100%
Xylene	95%
Methyl ethyl ketone	~100%
Methyl isobutyl ketone	74%
Butyl acetate	~100%
Propionic acid	0%
TOTAL	~59%

As result of analysis of flue gas material composition is shown as table 3 at inlet and outlet. About over 50% odor materials are converted to non-odor molecular composition at electrical potential difference of about over DC 30kV and pulse 42kV corona discharge. Especially, we assumed that higher ammonia removal rate has ammonia unification with other materials physically or bond with other materials chemically. And positive micro pulsed plasma has very effective removal efficiency to organic compounds [7].

4 Conclusion

Pilot deodorization system experiment by using positive pulsed corona discharge had been performed. The main findings in this development research can be summarized as follows.

1) Plate-rod type positive pulsed corona discharge can be applied to deodorization system.
2) Positive pulsed corona discharge has effective removal rate of organic compound.
3) Total deodorant materials removal rate is over 50% in positive corona discharge but ammonia and hydrogen sulfide removal mechanism have not been clearly studied.
4) Plate-rod type deodorization system can scale-up easily because of simple structure.

5 References

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