Available online at www.sciencedirect.com
ScienceDirect
Journal of Electrostatics 65 (2007) 228–232
Journal of ELECTROSTATICS
www.elsevier.com/locate/elstat

The experimental research on electrode configuration and discharge characteristics of pulse discharge

Li Jie*, Shang Kefeng, Wu Yan, Wang Ninghui, Zhang Yi

Dalian University of Technology, Institute of Electrostatics & Specific Power, Dalian 116024, China

Received 9 November 2003; received in revised form 1 June 2004; accepted 15 August 2006
Available online 11 September 2006

Abstract

Wire–plate-type reactors with the pulse-induced plasma chemical process (PPCP) have been extensively investigated for flue gas cleaning such as SO_X and NO_X, and the electrode configuration of reactors such as the plate-to-plate spacing and the wire-to-wire spacing is directly related to the formation of discharge plasma and the utilization efficiency of discharge energy, so it is useful to study the electrode configuration in order to provide a basis for PPCP applications. In this paper, the influence of these factors such as the plate-to-plate spacing and the wire-to-wire spacing on the discharge characteristics was investigated using a positive, nanosecond pulse generator. Some experimental results were obtained and discussed. It was found that when the wire-to-wire spacing (a) and the plate-to-plate spacing (c) of reactors satisfied the relation below, $a/c = 0.4 - 0.6$, the primary streamer energy was more bigger.

Keywords: Wire–plate electrode; Electrode configuration; Discharge characteristics; Pulsed discharge plasma

1. Introduction

Since Masuda first utilized corona plasma produced by a nanosecond pulse generator to remove NO_X and SO_2 from flue gas in 1986 [1], scholars have extensively investigated the pulse-induced plasma chemical process (PPCP), and have achieved some valuable results. Masuda et al. mainly investigated the relationship between the denitrification efficiency and these factors such as discharge energy, flow rate of flue gas, residence time and temperature of reactors [1,2]. Mizuno et al. [3,4] studied the effect of wet and semi-wet-type plasma reactors on desulfurization and denitrification efficiency, and concluded that pulse voltage with DC-bias voltage was more useful for desulfurization and denitrification. Chang et al. [5] studied the reduction of NO_X by a corona radical injection method. Wu et al. [6] utilized the water vapor activation process for producing more radicals to improve the entire desulfurization efficiency of flue gas. Fujii and Rea [7] researched the effect of circuit parameters on pulse discharge characteristics, and Wang et al. [8] investigated the matching relationship between the pulse generator and the reactor, and achieved the primary parameters influencing pulse–voltage waveforms. Oda et al. [9] utilized nonthermal plasma with a combination of additives and catalyst to treat nitric oxide and achieved 90% NO_X removal efficiency. Simultaneously, researchers started to carry out large-scale experimental investigations for industrial application. Dinelli et al. [10], Mok and Nam [11], and Wu et al. [12] carried out desulfurization and denitrification research with a flow rate of 1000, 3228 and 12,000–20,000 $N\,m^3/h$, respectively.

In this paper, the effect of electrode configuration (including electrode spacing and corona wire distribution) on pulse discharge characteristics (including peak pulse voltage, DC-bias voltage, energy of pulsed discharge and primary streamer) was studied.

2. Experimental instruments

The schematic diagram of a wire–plate-type reactor is shown in Fig. 1. In our experiments, the frame (with dimensions of $H \times L$: 85×190 cm) made by steel pipes and corona wires was used as anode, two parallel steel plates

*Corresponding author. Tel.:/fax +86 411 84708576.
E-mail address: lijie@dlut.edu.cn (L. Jie).

0304-3886/$ - see front matter
doi:10.1016/j.elstat.2006.08.003

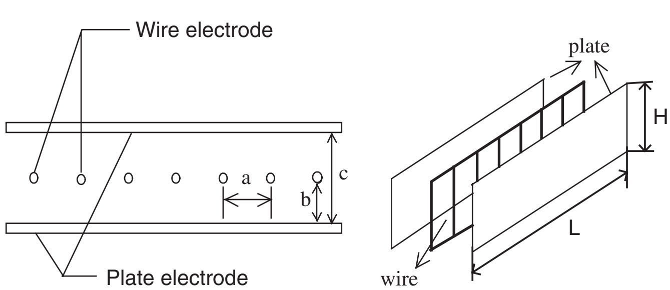
with dimensions of $100 \times 200\,cm^2$ were used as ground electrode, and rectangular steel wires with dimensions of $4 \times 4\,mm^2$ were used as corona wires. The plate-to-plate spacing (c) and the wire-to-wire spacing (a) were adjustable. The pulse high-voltage was supplied by a positive narrow pulse generator with a rotary spark-gap switch. The schematic of the circuit and experimental setup is shown in Fig. 2. The rise time of pulse voltage was less than 100 ns, the width was in the range of 200–400 ns, and the peak pulse voltage was adjustable in the range of 0–100 kV.

The voltage and current signals were sampled and recorded by an HP54810A digital oscilloscope (HP Corporation) with different probes, namely voltage probe HV-100 K (PEEC of Japan), and current probe (Tektronix Corporation of USA), respectively. The discharge energy was simultaneously calculated and analyzed. The static parameters (mainly the reactors' capacitance and inductance when reactors are not supplied with pulse voltage) of wire–plate discharge system were measured with PM6303A multi-analyzer (FLUKE Corporation of USA).

3. Results and discussion

3.1. Relations between plate-to-plate spacing and discharge characteristics

Table 1 shows the effects of the plate-to-plate spacing (c) on the peak pulse voltage, DC-bias voltage and single discharge energy. In our experiments, the plate-to-plate spacings were 15, 20 and 25 cm, and the wire-to-wire spacings (a) were 6 and 9 cm, respectively. The value of the pulse-forming condenser was 2 nF and the output of the DC high-voltage generator was 85 kV. Analyzing the data in Table 1, we see that the peak pulse voltage (V_p) and the DC-bias voltage (V_b) increased with the augment of the plate-to-plate spacing (c) at the fixed wire-to-wire spacing (a) and output of the DC high-voltage generator; however, the single pulse energy (W) decreased with an increase in the plate-to-plate spacing (c).



(a: Wire-to-wire spacing, b: Wire-to-plate spacing, c: Plate-to-plate spacing)

Fig. 1. Schematic of electrode configuration in a wire–plate-type reactor.

When the number of the corona wires and the wire-to-wire spacing are fixed, the wire-to-plate spacing is related to the static parameters (mainly the static capacitance and inductance) of reactors, the static capacitance of reactors decreases correspondingly with an increase in the wire-to-plate spacing. We think the reasons for our experiments are as follows: the inception voltage of streamer corona increases with the augment of the wire-to-plate spacing, the wider the wire-to-plate spacing is, the higher the inception voltage of streamer corona needs; but after the streamer corona discharge starts, the applied voltage has little influence on the development of streamers. When the wire-to-plate spacing is narrow, streamer corona discharge of reactors starts at relatively lower applied voltage, and then the increase of applied voltage has little influence on the peak pulse voltage. On the other hand, streamer corona discharge of reactors with wide wire-to-plate spacing starts at higher applied voltage, so the peak pulse voltage is higher than that of the narrow wire-to-plate spacing; similarly, residual voltage rises with an increase in wire-to-plate spacing after streamer corona quenches. But when wire-to-plate spacing is narrow, the density of the streamer corona and the primary streamer energy are bigger.

3.2. Relations between wire-to-wire spacing and discharge characteristics

In the experiments below, when the plate-to-plate spacings were 15 and 20 cm, the numbers of discharge

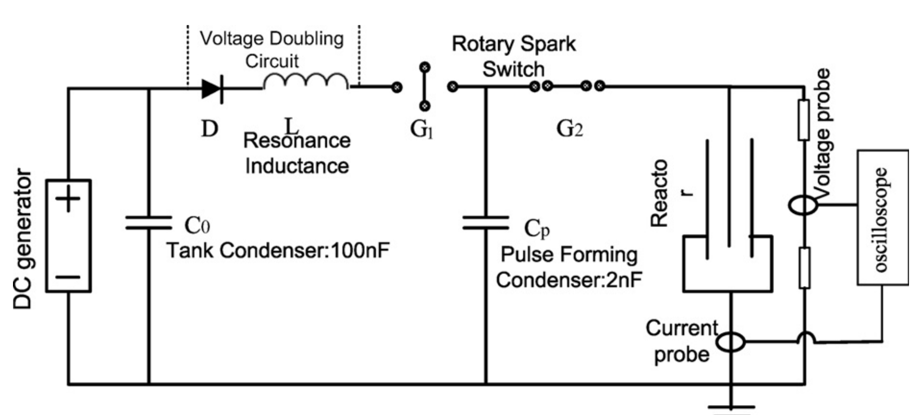


Fig. 2. Schematic of the circuit and experimental system.