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Review

Research on the influence of conductivity to pulsed arc electrohydraulic discharge in water

Lu Zhu [a], Zheng-Hao He [a,*], Zhi-Wen Gao [a], Fa-Li Tan [a], Xin-Gui Yue [a], Jen-Shih Chang [b]

[a] State Key Laboratory of Advanced Electromagnetic Engineering and Technology, School of Electrical and Electronic Engineering, Huazhong University of Science and Technology, Hubei 435400, PR China

[b] McIARS and Department of Engineering Physics, McMaster University, Hamilton, Ontario, Canada L8S 4M1

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A B S T R A C T

Pulsed arc electrohydraulic discharge (PAED) is a kind of thermal plasma arc discharge phenomenon which can generate strong pressure wave, ultraviolet ray and active groups. Therefore, PAED can act as a significant role applying on the technology of water treatment and it has broad application prospects. Compared with the existing water treatment mechanism, the technology of PAED possesses the most sterilization efficient and no secondary pollution. There are a huge number of plasma, active groups and gas liquid mixtures generated between the two arc electrodes in the water medium when the streamer discharge voltage is 3∼5 kV. In addition, water conductivity is also changed with the development of pulse arc electrohydraulic discharge which should be the prime importance in the process of PAED. In this article, firstly we analyzed the discharge mechanism on the process of pulsed arc electrohydraulic discharge. After that how the conductivity had played a major role in the process of pre-breakdown discharge and the main discharge processes will be discussed in detail. Experiments were conducted to research the relation among the conductivity, the pressure wave, active groups, ultraviolet light, discharge current and voltage generated from PAED. In finally the result can become a basis for using the water treatment tech of pulsed arc electrohydraulic discharge on different conductivity.

1. Introduction

Along with the development of water treatment technology, the application of combining the plasma technology with it has showed enormous advantage than others by right of its low energy consumption and no secondary pollution factors [1], [2]. Generally, among different plasma electrohydraulic technologies which are mainly based on pulse corona (PCED) [3], spark discharge [4], and pulse arc electrohydraulic discharge, etc. In principle, bacteria in water can be high-efficiently sterilized by physical effects (pressure wave, UV) and chemical effects (OH^-, O_3, free radical) which are generated by the process of electrohydraulic discharge (ED) [5].

Pulsed arc electrohydraulic discharge (PAED) is a thermal plasma arc discharge phenomenon which can generate strong pressure wave (10^6–10^8 Pa), ultraviolet ray ($\geq 10^5$ counts) and high concentration active groups. Compared with other water treatment technology, PAED has the absolute advantage by virtue of its superior treatment efficiency. The resultant generated by electrohydraulic discharge shows closely associated with the water conductivity whether electrohydraulic discharge is the pulse corona or pulse arc discharge. When the other influencing factors keep invariant, influence of the water conductivity can directly determines the main discharge types. Compared with PCED, the discharge voltage ($U_{dv} = 2$–5 kV) and discharge current ($I_{dv} \geq 10$ kA) of PAED show much higher than it and has obvious advantages on the water treatment technology [6].

In recent research, the phenomenon of PAED which includes mainly the pre-breakdown process, the development process of streamer discharge, and main discharge process. The variety value of conductivity majorly influence the formation of the initial plasma between the electrodes submerged in water, thus the pulse width of pre-breakdown voltage changes correspondingly from 200 μs to below 1 μs. In the development process of streamer discharge, before the positive streamer reached negative electrode, the length of streamer altered on account of water conductivity [7]. When the main discharge process happens, with the phenomenon of drastic discharge, a large number of plasma ($n \geq 10^{18}$ ion/cm^3) and free radical are generated in very short time ($t_g \leq 1$ μs). During this process, the water conductivity affects the ionization and the free radical concentration. Therefore, water conductivity is the

* Corresponding author. Tel./fax: +86 (0) 2787558970.
E-mail addresses: luzhu.hust@gmail.com, zhulu19870408@126.com (L. Zhu), hzh@mail.hust.edu.cn (Z.-H. He).

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determinants factor of the properties of pulse discharge in water [8].

Ever since the fifties years, experimental investigations and profound theoretical analysis were spent on the mechanism of how the water conductivity affected the electrohydraulic discharge by domestic and foreign scholars. H.M. Jones et al. observed the relation between liquid conductivity and the concentration of hydroxyl radical when the discharge voltage was 30 kV and the distance of the electrodes submerged in water was 10 mm [9]. The PCED system decolorizing efficiency on multiple needle plate electrodes [10] in the case of different liquid conductivity was carried out by H. Wang et al. J. Sidney Clements pointed out the complexity of electrohydraulic discharge process which was closely associated with water conductivity [11]. Nowadays, the principal orientation of research was PCED and spark discharge. In opposite, the influence of water conductivity on PAED and its discharge rule will be discussed in detail subsequent.

2. Experimental apparatus and methods

The experimental circuit of PAED is shown in Fig. 1. On the left side of the transformer T is the indicator and control equipment. VD_1, VD_2, VD_3, VD_4 are high voltage silicon stacks with a forward break-over voltage of 100 kV and they are composed the full-wave rectifying circuit. R is a resistor (10 kΩ/1000 W) which prevents the oversize of current gradient in charge circuit (dI/dt). Pulse capacitor C is used as the energy stored component in this circuit with a capacitance of 20–320 μF. The circuit of automatic grounding is designed to keep pulse power supply safety. The discharge gap range is from 0.5 mm to 1.5 mm. The single-pulse energy can be calculated with the formula: $W = 1/2\ CU^2$.

Fig. 2 shows the diagram of the PAED experiment system. Applied voltage is measured by a high voltage probe (Tektronix P6015A) and the current of discharge circuit is measured by ammeter shunt (GF-1, top measure current is 60 kA, 0.0037932V/A). The waveforms of discharge voltage and current will be showed on a digital oscilloscope (Tektronix TDS2024B). The waveforms of the pressure are measured by the piezoelectric type pressure sensor (CY-YD), and then the voltage signals will be sent to the electric amplifier (YE5853B) which can be displayed on the digital oscilloscope. The water conductivity is measured by the conductivity meter (DDS-200) and its measuring range is from 1 μS/cm to 200 mS/cm. The spectrum can be shown on the spectrometer (TCD 1304Ap).

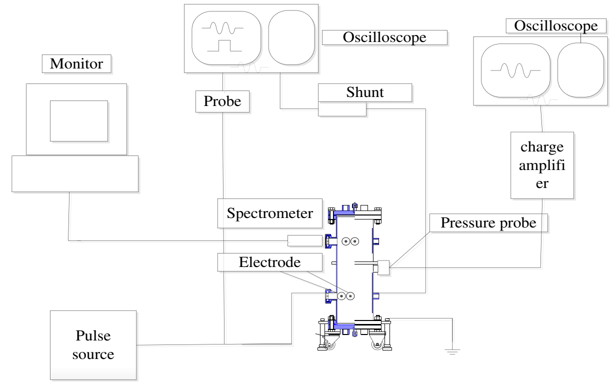

Fig. 2. Schematic diagram of experimental apparatus showing pulsed power supply, test cell, and detection system.

3. Results and discussion

Typical discharge current and discharge voltage waveforms are shown in Fig. 3, when the pulse capacitance is 80 μF and the distance between is 1.0 mm. After a discharge between the electrodes of pseudo spark switch, the water arc gap could not breakdown immediately. It is due to the process of pre-breakdown time. And its duration time usually below 100 μs. Because of the influence of the water conductivity, before the breakdown of the water arc gap happened, the micro current existing (generally range is from 1 mA to 100 mA) between the water arc gaps which is generally referred to as the leakage current. And it is closely related to conductivity and distance of the water arc gaps [12]. If the water conductivity is below 1 mS/cm (mostly tap water or lake water), the numerical value of pre-breakdown time delay can exceed 100 μs which is considerably larger than the breakdown time delay ($t_d \leq 1$ μs) [13]. The oscillation existing in the discharge waveforms

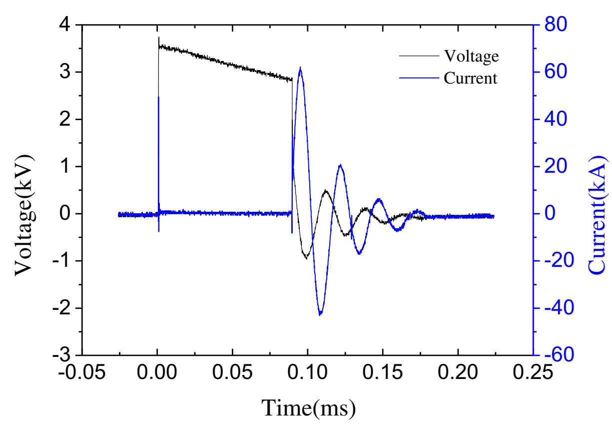

Fig. 3. Waveforms of discharge voltage, current ($\sigma = 0.628$ mS/cm).

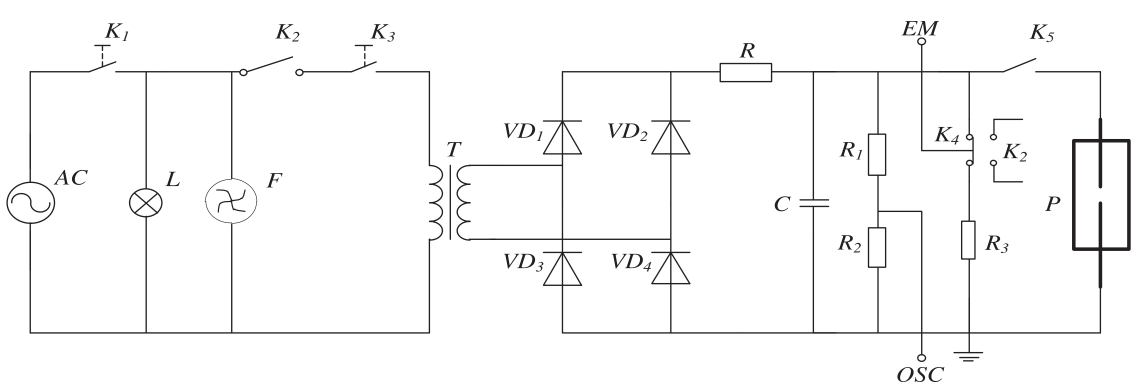

Fig. 1. Experimental circuit of PAED.