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脉冲流光电晕放电反应器中二次流光能量的研究

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摘　要: 实验研究了线－板式脉冲流光电晕脱硫反应器的线线间距、线板间距、脉冲成形电容及初级电压对二次流光能量及能量利用率的影响, 实验结果表明, 当反应器线线间距一定时, 增大反应器的线板间距可以降低二次流光的能量; 线线间距与线板间距的匹配对二次流光能量和能量利用率有很大影响, 当线线间距为线板间距的 0.8～1 倍, 反应器的二次流光能量减小, 能量利用率达到最大; 减小脉冲成形电容、初级电压也能减小二次流光的能量, 提高反应器能量利用率。

关　键　词: 脉冲流光电晕放电; 二次流光; 能量利用率
中图分类号: X511; TK01.9　　文献标识码: A

1　引　言

利用脉冲流光放电产生非热等离子体进行烟气脱硫是一种有效的、具有广阔应用前景的干式脱硫方法[1～2]。流光放电由 Loeb、Meek 等人提出后[3～4], 在实验及理论方面得到了广泛的研究[5～7], 但脉冲流光放电机理仍未得到充分的认识, 特别是对脉冲放电过程中二次流光的研究还处在初级阶段[5, 8]。二次流光与一次流光具有不同的特性, 一次流光的电子能量是二次流光的 5～10 倍[8]。脉冲流光放电脱硫正是利用一次流光放电的高能电子产生活性自由基来脱除二氧化硫, 而二次流光对二氧化硫的脱除不起作用, 只能增加能量的消耗。在实际脉冲流光放电烟气脱硫应用中, 二次流光放电不可避免。实验通过研究线－板反应器的电极配置、脉冲电路成形电容及初级电压对二次流光能量及反应器能量利用率的影响, 来降低二次流光的产生, 使放电能量尽量以一次流光放电形式注入到反应器中, 达到节约能耗的目的。

2　实验装置及测试方法

实验反应器为线－板式结构(见图 1)[9], 板电极为 2 000 mm×800 mm, 电晕线采用 4 mm×4 mm 的星型线。电晕线垂直均匀分布在板电极之间, 线板间距 h 和线线间距 s 可按实验要求进行调整。脉冲电压由旋转火花间隙式正极性窄脉冲电源提供, 其电路及实验系统如图 2 所示。

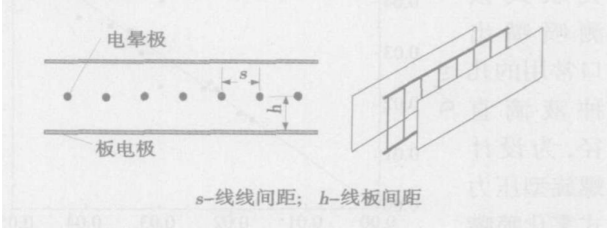
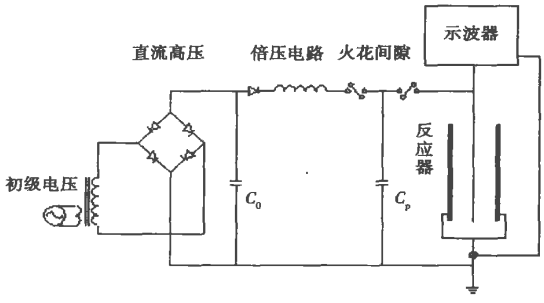


图 1　线－板式反应器结构示意图



C_0—储能电容; C_p—脉冲成形电容

图 2　脉冲电源电路原理和实验系统

脉冲电压用日本脉冲电子公司的 HV－100 K 高压探头测量, 脉冲电流用美国泰克公司的 Tektronix 6302 电流探头测量, 脉冲电压电流波形由美国惠普公司的 HP54810A 数字存储示波器取样。

脉冲电压前沿上升时间在 100 ns 以内, 脉宽为 300～500 ns, 脉冲电压峰值可达 100 kV。

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注入反应器的单次脉冲总能量(W)可由示波器记录的电压与电流脉冲直接相乘得到的功率脉冲在脉冲时间内积分得到。一次流光能量(W_p)及二次流光能量(W_s)可在其对应的时间内积分得到(见图 3)。实际注入反应器的单次脉冲总能量由一次流光能量和二次流光能量组成, 所以, 二次流光存在与否将决定反应器能量利用率的大小。在实验中, 脉冲有效能量利用率 $\eta_e = W_p / W$。

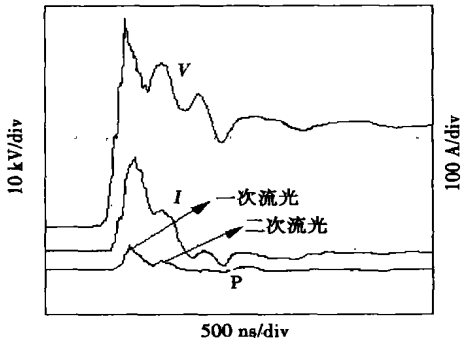

图 3　脉冲电压、电流、功率波形

3　结果与分析

3.1　线板电极配置的影响

3.1.1　线线间距的影响

在一定实验条件下, 线线间距的改变对二次流光能量具有一定的影响, 并存在一定的规律性。在正常流光放电情况下, 随着线线间距的减小, 二次流光能量减小, 当线线间距减小到一定值后, 二次流光能量反而增大(见图 4)。因为在一定线板间距下, 线线间距的变化引起反应器脉冲流光放电特性的变化, 当线线间距较大时, 脉冲一次流光能量不易释放, 脉冲电压拖尾较高[9], 导致二次流光放电, 能耗增大。随着线线间距的减小, 反应器脉冲流光放电特性得到改善, 二次流光放电减弱, 二次流光能量降低。当线线间距过小, 线线间的电场干扰较大, 同样在这种情况下, 脉冲一次流光能量也不易释放, 且线线间距的减小使得板极附近的电场强度增大, 易于二次流光的产生, 并向火花放电发展。从图 4 可看出, 在固定的线板间距下, 初级电压及脉冲成形电容(C_p)一定时, 当线线间距(s)为线板间距(h)的 0.8 ~1 倍时, 二次流光能量较小, 反应器脉冲有效能量利用率达到最大。在此线板配置下, 脉冲有效能量增大, 并以一次流光形式注入到反应器内[9]。

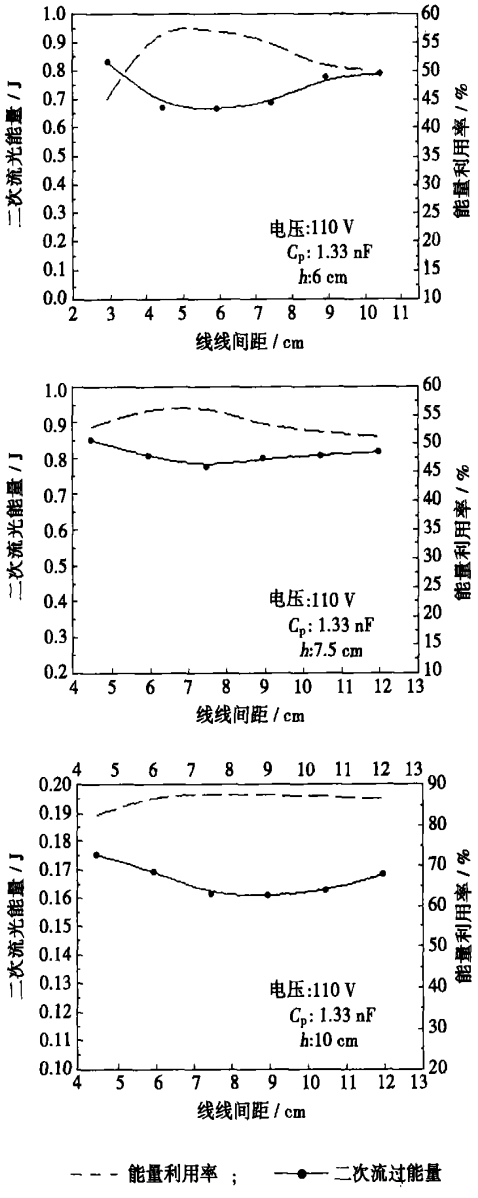

图 4　线线间距与二次流光能量及能量利用率的关系曲线

3.1.2　线板间距的影响

从图5 和图 6 可看出, 线板间距对二次流光能量、能量利用率有很大的影响。当初级电压、C_p 一定时, 随着线板间距的增大, 二次流光能量降低, 脉冲有效能量利用率增大。尽管增大线板间距时, 单次脉冲能量减小[9], 但由于线板间平均电场强度的减小及流光传播距离增大, 大大抑制了二次流光的发生, 提高了能量利用率。例如, h 为 10 cm, C_p 为 1.33 nF, 初级电压为 120 V 时, 二次流光能量低于 0.2 J, 能量利用率达到近 90%, 脉冲能量主要以一次流光放电形式注入反应器中。且板间距的增大,

施加电压有很大的选择范围。实际工业应用中采用高电压、大功率的电源时，选择大的板间距更具有实用价值。

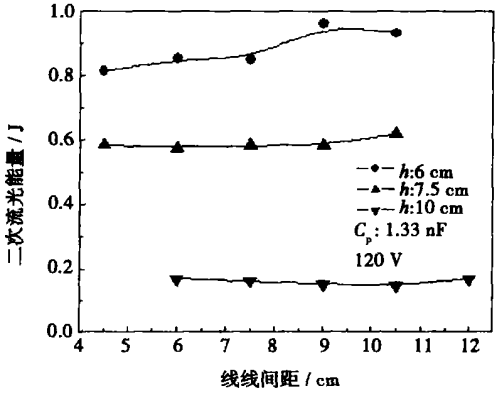

图 5 线板间距对二次流光能量的影响

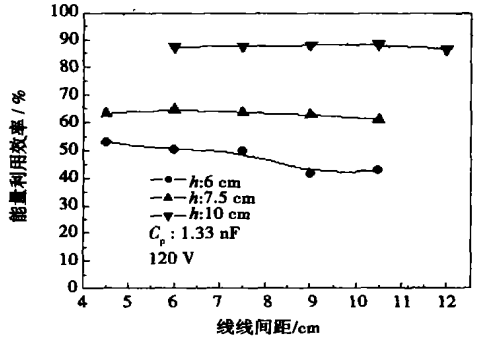

图 6 线板间距对能量利用率影响

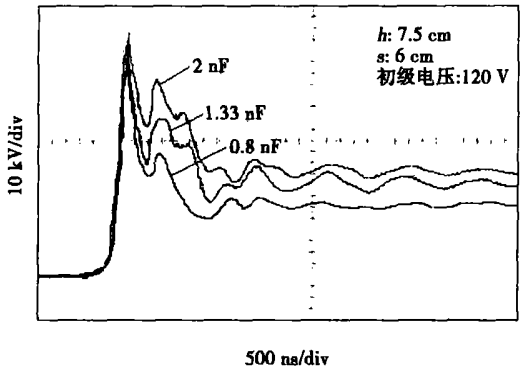

图 7 不同成形电容下的电压波形

3.2 脉冲成形电容的影响

图 7 为在不同脉冲成形电容下的脉冲电压波形，当脉冲成形电容增大时，脉冲电压拖尾抬高，脉宽增大。图 8 和图 9 显示，增大脉冲成形电容，二次流光放电能量增大。尽管在放电试验中随着脉冲成形电容的增大，单次脉冲能量增大，但脉冲有效能量的比率在减小，即能量利用率减小。脉冲成形电容的大小是影响脉冲流光放电特性的主要因素之一。电容取值增大，其能量在段时间不能迅速泄放，使得脉宽增加，电压拖尾抬高，容易发生二次流光放电。所以，选择成形电容时，在遵循脉冲电源与反应器匹配的原则下，尽可能采用小电容，以提高能量利用率。

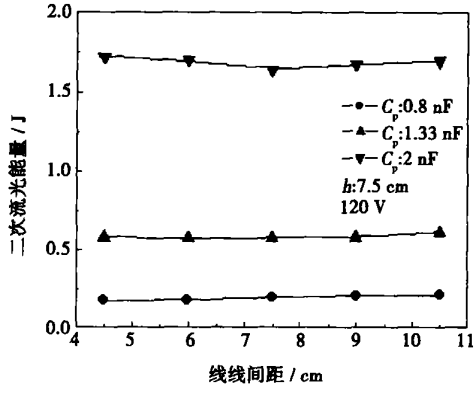

图 8 脉冲成形电容对二次流光能量的影响

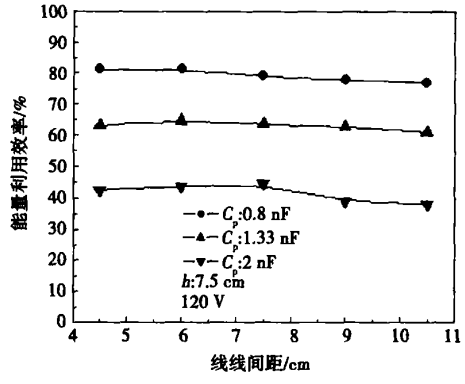

图 9 脉冲成形电容对能量利用率的影响

3.3 初级电压的影响

由图 10 和图 11 可看出，初级电压对二次流光的影响很大，随初级电压的增大二次流光的能量增大，脉冲有效能量利用率减小。可见，增大初级电压，施加在反应器上的脉冲电压峰值增大，单次脉冲能量增大，一次流光能量增大，同时也增大了二次流光能量，从而使得能量利用率减小。电压是影响二次流光放电最主要原因，过高电压易于产生二次流光放电及火花放电，所以，在脉冲成形电容及反应器结构配置一定下，选择合适的施加电压是控制二次流光产生的关键。

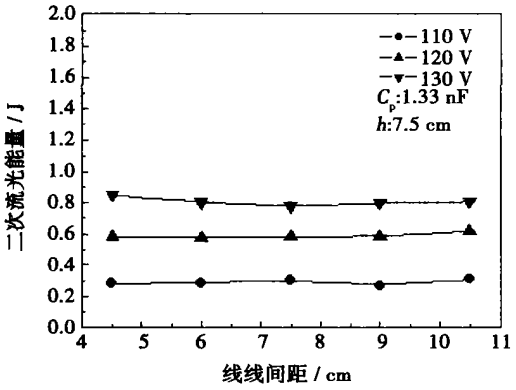

图 10　初级电压对二次流光能量的影响

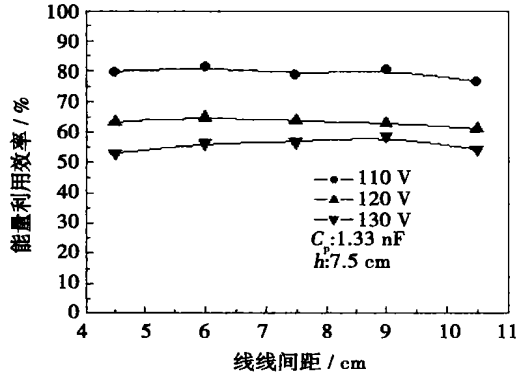

图 11　初级电压对能量利用率的影响

4　结　论

线—板式脉冲流光电晕脱硫反应器中二次流光的存在会降低脉冲有效能量利用率, 实验研究了反应器线线间距、线板间距、初级电压、脉冲成形电容对二次流光能量及有效能量利用率的影响, 得出: 线板间距一定时, 线线间距为线板间距的 0.8 ~ 1 倍时, 二次流光能量较小, 能量利用率增大; 增大线板间距, 减小脉冲成形电容, 减小初级电压可减小二次流光的能量, 达到控制二次流光的目的, 降低能耗, 提高能量利用率。

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(辉　编辑)

新技术 新产品

汽轮机热膨胀诊断系统

据《Теплоэнергетика》2005 年 6 月号报道, 新研制了 СДАРТ (汽轮机汽缸壳体绝对热膨胀诊断系统) 诊断系统。该系统能对热电站设备进行工艺检查和动力设备修理完成汽轮机设备在启动—停机工况时状态进行监控诊断。

主要诊断参数是: 汽缸壳体的绝对热膨胀、支座和横梁的倾斜、机脚相对于汽轮机汽缸横键的热位移。长期监测参数的总数量可以达到几十个。

探讨了诊断机匣部件变形的各种现代化测量系统, 分析这些变形允许客观地判断汽轮机的状态, 并编制必要修理工作的清单, 以及进行修理前的诊断。

介绍了 СДАРТ 诊断系统的总特性、系统的设备、系统的软件及其应用情况。

(吉桂明　供稿)

对喷流除尘性能影响因素的正交实验研究＝**An Orthogonal Experimental Study of Factors Affecting Dust Removal Performance by Counter Jet Flows**[刊, 汉] /ZHANG Ming-xing, CHEN Hai-yan, YAN Cui-ping, et al (Environment and Resource College under the Southwest University of Science and Technology, Mianyang, China, Post Code: 621010) // Journal of Engineering for Thermal Energy & Power. — 2006, 21(5). —500～504

A decrease in dust removal efficiency may be caused by the use of a horizontal type counter jet-flow structure, resulting in a portion of dust particles being adhered to equipment walls opposite to spray nozzles. To cope with the above problem, an inclined-type counter jet flow-based dust removal technique was adopted to collect dust particles of the ammonium sulfate and ammonium nitrate mixture with an orthogonal table $L_{16}(45)$ being utilized to optimize experimental parameters. Investigations were performed at four levels of magnitude respectively for the five main parameters affecting the dust removal performance, namely, nozzle velocity, dust-laden concentration, horizontal spacing of nozzles, inclination angle and water consumption of atomized water spray for moistening dust-laden gas flows. As a result, an optimum scheme was identified as follows: nozzle velocity 25～27 m/s, dust-laden concentration 0.55～0.65 kg/m^3, spacing of spray nozzles 0.2～0.25 m, inclination angle 40～60 degrees and water consumption 0.21～0.25 kg for each kilogram of dust. The experiments have proved that the dust removal efficiency under the above condition can attain a maximum of 98.6% and the moistening of dust-laden gas flow by spraying atomized water has the greatest impact on the dust removal efficiency. Through observations, it has been found that the inclined-type counter jet flow can effectively avoid the adhesion of dust particles on the equipment wall surfaces. **Key words**: counter jet flow for dust removal, dust removal efficiency, influencing factors, orthogonal experiment, inclination type

压力式螺旋型喷嘴雾化特性实验研究＝**An Experimental Study of Pressure-type Spiral Nozzle Atomization Characteristics**[刊, 汉] /LIU Nai-ling (Thermal Energy Engineering College under the Shandong Architectural Engineering University, Jinan, China, Post Code: 250014), ZHANG Xu (Mechanical Engineering College under the Tongji University, Shanghai, China, Post Code: 200092) // Journal of Engineering for Thermal Energy & Power. — 2006, 21(5). —505～507

Liquid atomization represents a most important scientific issue playing a key role in the study of two-phase flows. Being widely used in energy and power supply units as well as in environmental engineering projects, it is of major significance to conduct a systematic study of the liquid atomization. A kind of pressure type nozzles, the spiral nozzles can provide a fine and dense liquid mist and have found relatively widespread applications. A criterion relationship featuring the liquid droplet diameters of spiral nozzles has been established by using a dimensional analytic method. An empirical formula applicable to several kinds of diameters (D_{32}, $D_{0.1}$, $D_{0.5}$, $D_{0.9}$) of TF-type nozzle atomized particles were regressed by utilizing a least square method. The results show that the empirical formula thus regressed is characterized by a comparatively good correlation. Through the formula one can predict the diameters of particles at the nozzle outlet, thus providing a theoretical basis for the design and application of spiral type nozzles. **Key words**: spiral type nozzle, atomization characteristics, atomization similarity criterion, empirical formula

脉冲流光电晕放电反应器中二次流光能量的研究＝**A Study of the Secondary Streamer Energy in a Pulse-streamer Corona-discharge Reactor**[刊, 汉] /DONG Bing-yan, XIE Wen-juan, ZHANG Da-chao (Environmental and Architectural Engineering College under the Jiangxi University of Science and Technology, Ganzhou, China, Post Code: 341000), WU Yan (Electrostatic and Special Power Source Research Institute under the Dalian University of Science and Technology, Dalian, China, Post Code: 116024) // Journal of Engineering for Thermal Energy & Power. — 2006, 21(5). —508～511

An experimental study was conducted of the impact of the wire-wire spacing, wire-plate spacing, pulse-formation capacitance and primary voltage of a wire-plate type pulse-streamer corona-discharge reactor on secondary streamer energy and

energy utilization rate. The experimental results show that when the wire-wire spacing of the reactor is constant, an increase in its wire-plate spacing can lower secondary streamer energy. The matching of the wire-wire spacing and wire-plate spacing can greatly influence the secondary streamer energy and energy utilization rate. When the wire-wire spacing is 0.8 ~ 1 times the wire-plate spacing, the secondary streamer energy of the reactor will be reduced and the energy utilization rate will attain its maximum value. A decrease in the pulse-formation capacitance and primary voltage can also reduce the secondary-streamer energy and enhance the energy utilization rate of the reactor. **Key words**: pulse-streamer corona discharge, secondary streamer, energy utilization rate

基于凝汽器强化传热技术的循环水系统节水研究=**A Study of the Water Savings of a Circulating Water System Based on the Intensified Heat Transfer Technology of a Condenser**[刊, 汉] /WANG Wei, SUN Feng-zhong, GAO Ming, et al (Energy and Power Engineering College under the Shandong University, Jinan, China, Post Code: 250061), WU Yan (Electrostatic and Special Power Source Research Institute under the Dalian University of Science and Technology, Dalian, China, Post Code: 116024) // Journal of Engineering for Thermal Energy & Power. — 2006, 21(5). —512 ~ 515

From the standpoint of enhancing the heat transfer coefficient of condensers, a concept of critical fouling heat-resistance is introduced under the precondition of keeping the vacuum unchanged. Through an analysis of the relation between critical fouling heat-resistance and circulation concentration ratio, the intensified heat transfer is studied in conjunction with the issue of circulating water savings. Moreover, through some specific examples, the water saving quantity is calculated. The study results show that when the vacuum of the condenser and other heat exchange conditions are kept unchanged, an increase in heat exchange coefficient at the steam side of condenser heat exchange tubes can raise the critical fouling heat-resistance, thereby enhancing the concentration ratio of the circulating water and attaining the aim of saving water for the circulation water system along with the securing of sizable water-saving and environmental protection benefits. After an analysis had been conducted of a 300 MW power plant condenser that used intensified heat transfer tubes, it is found that the heat exchange coefficient at the steam side has markedly increased. Under the condition of attaining the vacuum set by the original design, the machine unit can as a result save water amounting to 869 000 tons each year. **Key words**: circulating water system, water saving, condenser, intensified heat transfer, critical fouling heat-resistance, concentration ratio

火电站负荷调度混沌变步长混合遗传算法=**Chaotic Variable Step Length-based Hybrid Genetic Algorithm for Load Dispatching at Power Plants**[刊, 汉] /LIAO Yan-fen, MA Xiao-qian (College of Electric Power under the South China University of Technology, Guangzhou, China, Post Code: 510640) // Journal of Engineering for Thermal Energy & Power. — 2006, 21(5). —516 ~ 520

By combining the ergodic character of chaotic movement with population searching character of genetic algorithm, a hybrid genetic algorithm based on a chaotic variable dimension gradient-drop was presented, which can be used to optimize load dispatching at power plants. The algorithm adopts a gradient drop method to conduct a local search of excellent individuals obtained from genetic variation and guide the evolution of the population. In conjunction with a chaotic optimization strategy, a self-adaptive step length can be produced, quickening the optimum-searching speed at the initial period of searching. With the searching gradually approaching the optimized point, by way of the small step length produced by chaos, it is possible to realize an accurate searching within a small range where an optimized solution is located. It has been found through an application of the optimized load dispatching at power plants that compared with the traditional genetic algorithm and officer-on-duty distribution method, the genetic algorithm can achieve an even higher efficiency in load dispatching optimization for power plants. Through an optimization searching of load distribution of power plants by using the hybrid genetic algorithm, the power-generation coal consumption rate for a whole power plant can be reduced by 0.29 ~ 1.07 g/(kW·h) compared with that of the officer-on-duty system, bringing about sizable economic benefits for the