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Current analysis of DC negative corona discharge in a wire-cylinder configuration at high ambient temperatures

Gang Xiao, Xihui Wang, Jiapeng Zhang, Mingjiang Ni*, Xiang Gao, Kefa Cen

State Key Laboratory of Clean Energy Utilization, Institute for Thermal Power Engineering, Zhejiang University, Hangzhou 310027, China

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ABSTRACT

To study the characteristics of DC negative corona discharge in a wire-cylinder configuration at an ambient temperature range of 350–850 °C, the *I*–*V* characteristics and the current composition are analyzed under different conditions. A simple method is proposed to determine the DC corona onset threshold voltage. At high ambient temperatures, in the DC negative corona discharge gap, some electrons are not attached to the electronegative gas molecules and move to the anode tube. Thus, these electrons form an electron current, which may account for most of the total discharging current. The ratio of the electron current to the total discharging current increases with increasing temperature. In a mixture of O_2 and N_2 and a mixture of CO_2 and N_2, the ratio of electron current increases with increasing N_2 content in the mixtures. The cathode material has little influence on the corona discharge characteristics at high ambient temperatures.

1. Introduction

The integrated gasification combined cycle (IGCC) and the advanced pressurized fluidized-bed combustion (PFBC) technologies promise electricity generation with substantially greater thermodynamic efficiencies and reduced environmental effects [1,2]. For these power systems, the gasified gases at high temperatures enter gas turbines to generate power. To protect the downstream heat exchanger and the gas turbine components from fouling and erosion while cleaning the gas stream to meet the environmental emission requirements, it is critical for the power system to effectively remove the particles [3]. The objective in developing advanced power systems is to collect particles at temperatures between 370 °C and 595 °C for IGCC and 760–870 °C for PFBC [4].

Electrostatic precipitation is effective for removing the hazardous products from industrial flue gases and fine particles from the hot gas steam in wood combustion furnaces, etc. [5–8]. Particle charging is important for electrostatic precipitation, which is determined using the discharging characteristics of the reactor and the properties of the particles to be removed [9]. The particle charging mechanisms include the field charging using ion bombardment on the particles and the diffusion charging by ion diffusion, where the field strength and the ion concentration play the most important role [10–13].

However, the previous studies on electrostatic precipitation were performed with ambient temperatures lower than 400 °C [14]. The highest experiment temperature that we know is 680 °C [15]. In our previous work, the characteristic of DC discharge in a wire-cylinder configuration at an ambient temperature range of 350–850 °C was investigated [16]. In this work, we study the current composition of the DC negative corona discharge by analyzing the *I*–*V* characteristics and the corresponding discharging photographs in different atmospheres. We aimed to do some basic work for the application of electrostatic precipitation at high temperatures (above 400 °C).

2. Experimental methodology

2.1. General introduction

The schematic of the experimental system is shown in Fig. 1(a). A wire-cylinder discharging device with an inter-electrode gap of 29 mm is placed on the middle of the corundum tube with a length of 1.2 m and inner diameter of 74 mm. The stainless sleeve tube on the left side is connected with the corundum tube using flanges. The outer diameter of the stainless sleeve tube is identical to the inner diameter of the corundum tube. The tetrafluoroethylene gasket is placed in the flanges of the sleeve tube, through which two holes are cut to

* Corresponding author. Tel.: +86 571 87953290; fax: +86 571 87951616.
E-mail address: ceu_ni@zju.edu.cn (M. Ni).

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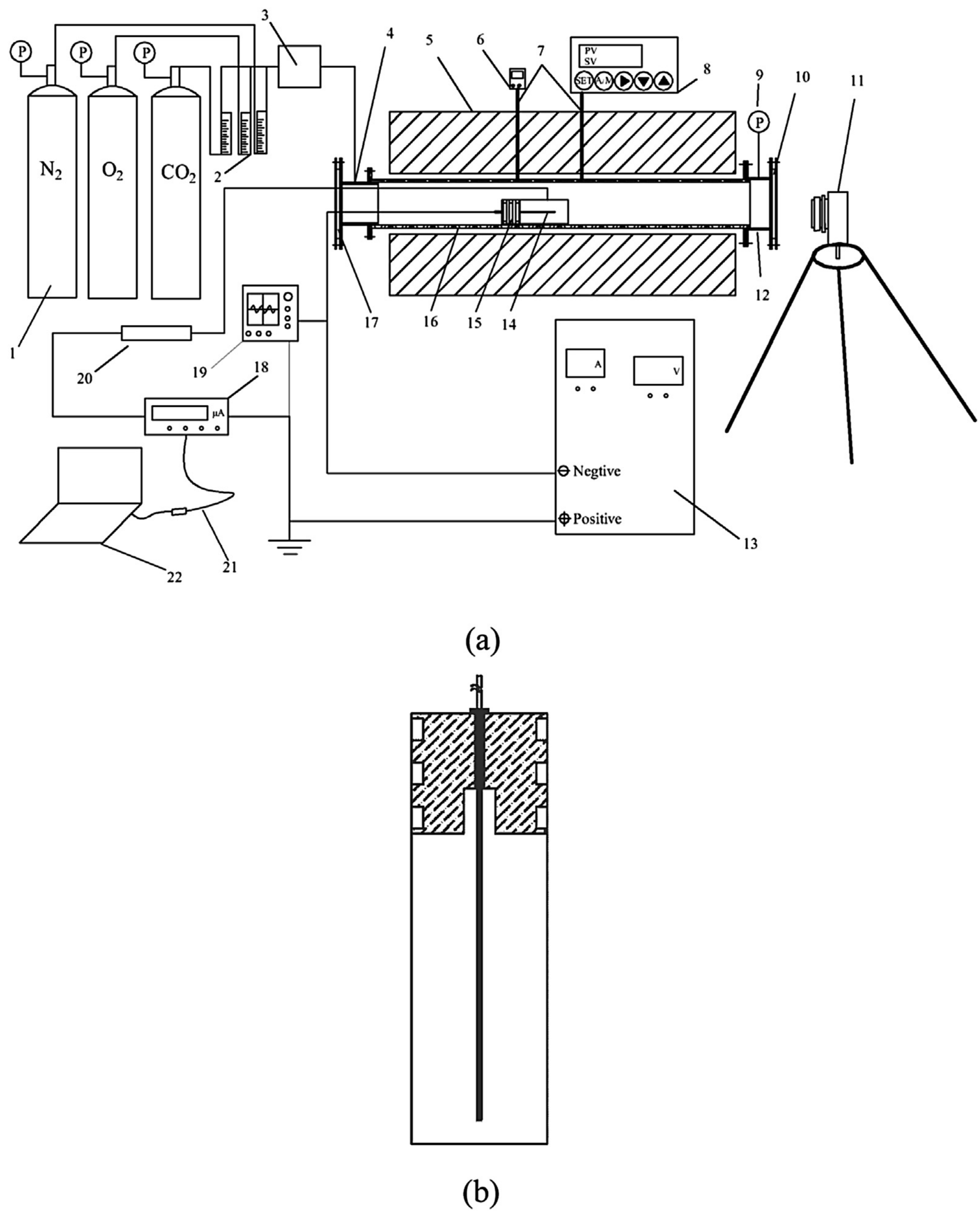

Fig. 1. Schematic of the experimental system. 1 – gas tank, 2 – flow-meter, 3 – gas mixing tank, 4 – stainless sleeve tube, 5 – heating furnace, 6 – temperature indicator, 7 – thermal couple, 8 – programmable temperature controller, 9 – pressure gauge, 10 – quartz glass, 11 – camera, 12 – gas outlet, 13 – negative high-voltage DC power supply, 14 – electrodes, 15 – porcelain, 16 – corundum tube, 17 – tetrafluoroethylene gasket, 18 – galvanometer, 19 – oscilloscope, 20 – protecting resistor, 21 – RS 232 convertor, 22 – computer.

pass through the anode and cathode conducting wires without connecting. The inner diameter of the stainless sleeve tube on the right side is identical to the outer diameter of the corundum tube. A piece of quartz glass is placed in the flanges to make it capable to take photos of the discharging process in the furnace. A Nikon D5100 digital camera is used. The exposure time of the camera depends on the brightness of the light in the furnace. All the photos are taken at steady-state.

Table 1
Properties of electrodes and gas media.

Electrodes	Electrode material	Diameter (mm)	Length (cm)	Gas media	Attachment	Ionization
Cathode	TP310S (06Cr25Ni20)	2	15	O_2 [18]	4.4 eV/0.058 eV	12.06 eV
	W-La_2O_3 (~2%wt La_2O_3)	2	15	CO_2 [19]	3.85 eV	13.3 eV
	Mo (99%wt)	2	15	N_2 [20]	–	15.6 eV
Anode	TP310S	12	18	N_2 [20]	–	15.6 eV
	TP310S	60	18			