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IGNITION CHARACTERISTICS OF BIAS PULVERIZED COAL JETS AT DIFFERENT INITIAL PULVERIZED COAL CONCENTRATIONS IN A REDUCING ATMOSPHERE

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ABSTRACT

To further advance low NO_x pulverized-coal (PC) ignition theory, guide the parameter design of PC burner of bias combustion technologies and enable the related numerical simulation work, combustion experiments for an Indonesian coal were conducted in a 250-kW pilot-scale Bias Combustion Simulator (BCS); multiple research means of combustion temperatures and flame spectra were used. The effects of initial Pulverized Coal Concentration (PCC) on the standoff distance, ignition mode and continuous flame region of bias PC jets in a reducing atmosphere were investigated. The results indicate that with increasing initial PCC for bias PC jets in the experiments, the standoff distance gradually decreased, the peaks of subsequent combustion temperature and light emission intensity gradually increased, the continuous flame regions became gradually concentrated, the flame stability became gradually stronger, and the ignition characteristics gradually improved. The initial PCCs changed the ignition mode of bias PC jets; there was homogeneous–heterogeneous combined ignition mode at initial PCCs of 0.33 and 0.41kg/kg; there was homogeneous ignition mode at an initial PCC of 0.53kg/kg. At different initial PCCs, the continuous flame region of bias PC jets leant obviously in the direction of the fuel-rich jet.

Keywords: bias pulverized coal jets, low NOx combustion technique, initial pulverized coal concentration, ignition characteristics, reducing atmosphere, Indonesian coal

1. INTRODUCTION

The low NO_x bias combustion technique is widely used in tangentially fired utility boilers in large-scale boiler[1, 2]. In this technology, the Primary Air (PA)/PC stream is separated into fuel-rich and fuel-lean streams, which are then introduced separately into the furnace and burned at a stoichiometric ratio away from normal combustion, to achieve strong ignition, NO_x emission reduction, and slagging prevention[2, 3].

In bias combustion, the initial PCC is defined as the mass ratio of PC to PA in the initial PA/PC jets, and the Bias Concentration Ratio (BCR) is defined as the concentration ratio of PC in the fuel-rich jet to that in the fuel-lean jet[4]. The variation of initial PCC will cause significant changes in the combustion atmosphere and temperature, which affect the ignition characteristics of PA/PC jets[5, 6]. Fuel-rich and fuel-lean streams of bias PC jets are burned in reducing and oxidizing atmospheres, respectively. Most studies have concentrated on the ignition characteristics of single-atmosphere and single jet PC streams, but such studies cannot adequately clarify the ignition process in bias combustion. It is necessary to use the 250-kW pilot-scale BCS which can simulate the straight-jet coal flame of bias PC burner in a tangentially fired utility boiler, to study the ignition characteristics of bias PC jets[3].

Air stage combustion is now being used for utility PC boilers to lower NOx emissions, but the primary combustion zone is in a reducing atmosphere[7], which decreases the PC combustion efficiency[8]. Combustion experiments were therefore performed on bias PC jets in a reducing atmosphere in our recent publications[9-11]. Using the previous research method, the effects of the initial PCC on the ignition characteristics of bias PC jets were studied in this study.

2. EXPERIMENTAL SECTION

A schematic diagram of the 250-kW pilot-scale BCS is shown in Figure 1[9-11]. The combustion took place in a reducing atmosphere. The air-to-coal stoichiometry was 0.75, the PA velocity was 16 m/s, the PA temperature was 85 °C, and the BCR was 4, which were applied and performed well in our previous studies[9-11]. Different experimental cases of variable initial PCC were realized through the PA ratio adjusting based on the constant total air supply flow and total fuel feeding flow, and the variable initial PCC experiments were performed using initial PCC = 0.33 kg/kg、0.40kg/kg and 0.53 kg/kg. During the hot-condition experiments, BCS was operated in a continuous and stable state that could be repeated to ensure data accuracy and repeatability. The average value of multiple measurements was used in the experiments to minimize errors. Details of the experimental method can be found in previous publication[9].

In this study, the standoff distance is defined as the position at which the intensity of the axial visible light in the coal flame spectrum reaches 10% of the average value of the maximum peak intensity, which was used as the criterion for determining the standoff distance in each variable experiment[9, 12]. Besides, the emission intensities of hydrocarbons and hot soot in the flame spectrum were used to investigate the ignition mode of the bias PC jets[13-15]. Furthermore, the axial differential temperature of the bias PC jets was obtained as the difference between axial temperature after coal feeding and axial blank temperature before coal feeding[9], which reflects the trend in heat release during bias PC combustion[16, 17]. Based on the heat release features of one heat peak for simultaneous burning of volatiles and chars and two heat peaks for sequential burning of volatiles and char[18], the ignition mode of the bias PC jets was determined[9]. The continuous flame delay distance is defined as the position at which the intensity of visible light reaches 50% of the average value of the maximum peak intensity[12, 13, 15]; this definition combined with the radical temperature distribution was used to determine the boundary of the continuous flame region [19].

Trafigura subbituminous coal sourced from Indonesia was used in the experiments; The proximate and ultimate analytical data is presented in Table 1. The pulverized coal used in the study had a full particle size

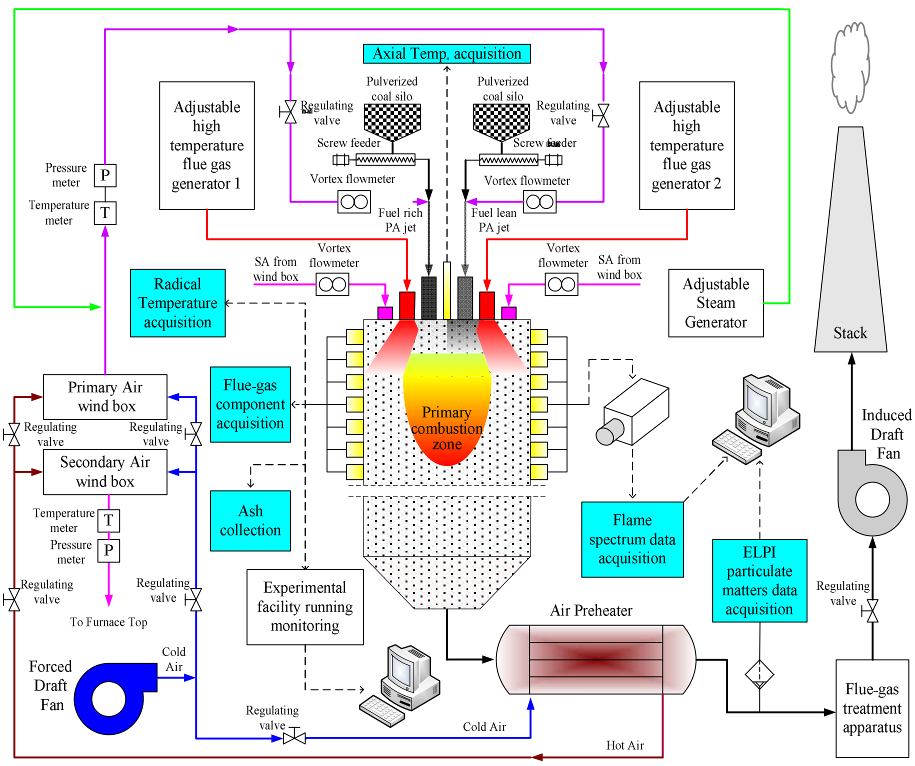

Fig 1 Schematic diagram of pilot-scale BCS system

distribution, and the PC fineness was R75 = 16% (i.e., the surplus after 75-µm sieving was 16%)[9-11].

Table 1 Proximate and ultimate analyses of coal

Proximate analysis (%, as received)				Low Heat Value
M_{ar}	V_{ar}	A_{ar}	FC_{ar}	(MJ/kg)
22.70	35.63	5.06	36.61	19.58
Ultimate analysis (%, as received)				
C_{ar}	H_{ar}	O_{ar}	N_{ar}	S_{ar}
51.77	3.70	15.50	0.85	0.42

3. RESULTS AND DISCUSSION

3.1 Standoff distance of bias PC jets ignition at different initial PCCs

Axial temperatures of bias PC jets ignition at different initial PCCs are shown in Figure 2. With increasing axial distance, the change trends of the axial

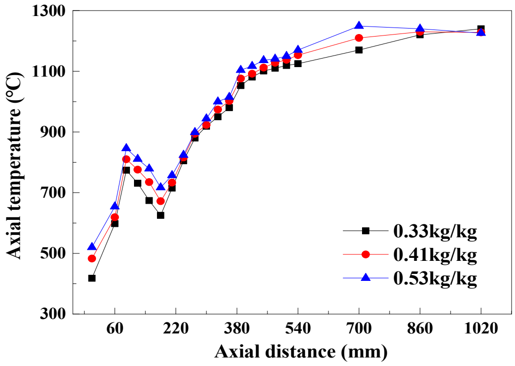

Fig 2 Axial temperatures at different initial PCCs

temperatures were similar to our previous findings[9], which reveals that the standoff distance of bias PC jets ignition at different initial PCCs should be an axial distance of 180-390 mm, in which the increasing trend of axial temperature became more intense as initial PCCs increased, because in this study, the higher initial PCC,

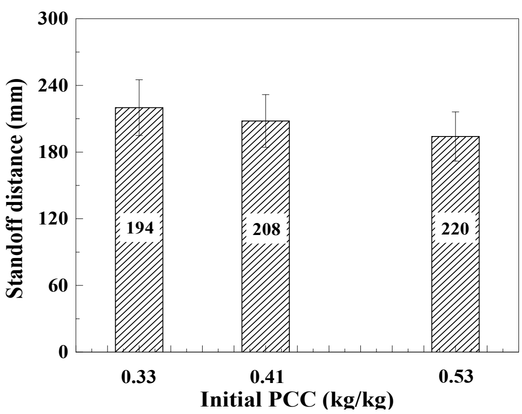

Fig 3 Standoff distances at different initial PCCs

the more volatile volatiles released in the ignition stage, which was beneficial to the PC ignition[20, 21].

The standoff distances of bias PC jets ignition at different PCCs are shown in Figure 3. The standoff distance gradually decreased as initial PCC increased. This is because in this study, with increasing initial PCC, the PA flow in the bias PC jets decreased, the ignition heat of PC jets correspondingly decreased; furthermore, as the air around the coal particles decreased, the thermal resistance of heat transfer to the coal particles decreased, which made the bias PC jets ignited in a shorter distance[20, 21].

3.2 Ignition mode of bias PC jets at different initial PCCs

The axial absolute irradiances of hydrocarbon and hot soot of bias PC jets ignition at different initial PCCs are shown in Figure 4, 5 and 6. Figure 4 and 5 show that at 220 mm axial distance, near the standoff distance for

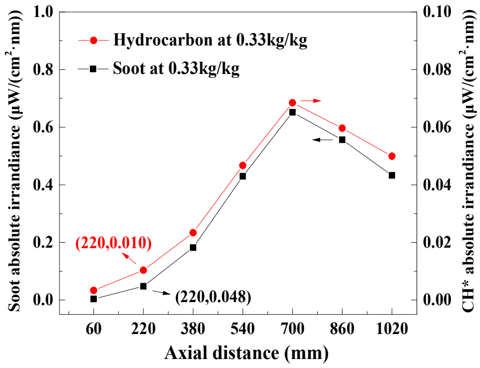

Fig 4 Axial absolute irradiances of hydrocarbon and soot at an initial PCC of 0.33kg/kg

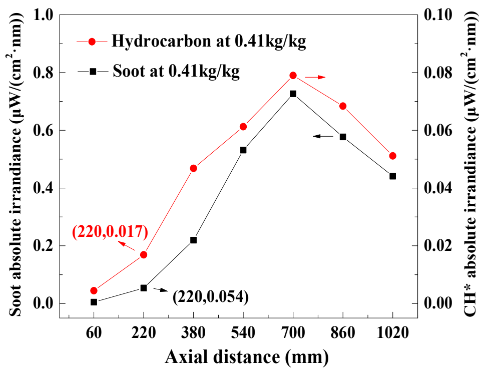

Fig 5 Axial absolute irradiances of hydrocarbon and soot at an initial PCC of 0.41kg/kg

initial PCCs of 0.33kg/kg and 0.41kg/kg, the axial absolute irradiance of hydrocarbons was lower than that of hot soot. The result shows that the volatile and char ignited simultaneously. Based on preliminary results, the ignition modes for initial PCCs of 0.33kg/kg and 0.41kg/kg are volatile and char homogeneous-heterogeneous combined ignition[9-11, 22]. Figure 6 shows that at 220 mm axial distance, near the standoff distance for initial PCC of 0.53kg/kg, the axial absolute irradiance of hydrocarbons was no less than that of hot soot. Based on preliminary results, the ignition mode for an initial PCC of 0.53kg/kg was volatile-phase homogeneous ignition[9-11, 22]. This is because with increasing initial PCC, the quantity of coal particles in the bias PC jet increased, then the volatile released from coal reached the homogeneous ignition conditions[6, 20].

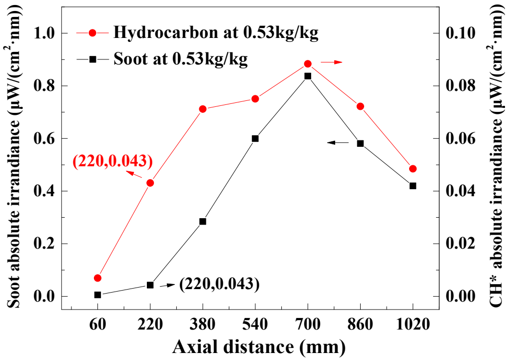

Fig 6 Axial absolute irradiances of hydrocarbon and soot at an initial PCC of 0.53kg/kg

The axial differential temperatures of bias PC jets ignition at different initial PCCs are shown in Figure 7. It is seen that at initial PCCs of 0.33kg/k and 0.41kg/kg, axial differential temperature has one obvious peak prior to an axial distance of 540 mm arise from the release of heat from simultaneous combustion of the volatiles and char, these results prove that the ignition modes of bias PC jets at initial PCCs of 0.33kg/k and 0.41kg/kg were homogeneous-heterogeneous combined ignition[9-11, 22]. Besides, at an initial PCC of 0.53kg/kg, the axial

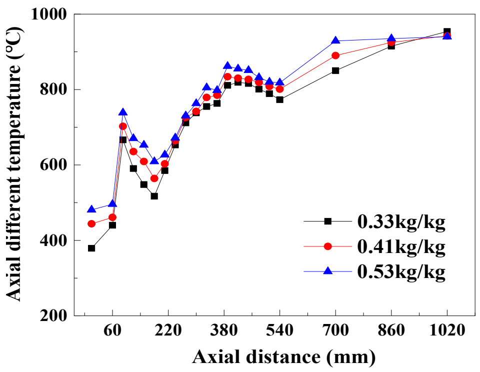

Fig 7 Axial differential temperatures at different initial PCCs

differential temperature has two obvious peaks prior to 540 mm. The first of the two peaks in the axial differential temperature distribution was caused by the release of heat from combustion of the volatile, and the second peak is caused by the release of heat from combustion of the char. These results also prove that the ignition mode of bias PC jets at an initial PCC of 0.53kg/kg was homogeneous ignition[9-11, 22]. These results show that the ignition mode of bias PC jets changed to homogeneous ignition mode from homogeneous-heterogeneous combined ignition mode when the initial PCC increased to 0.53kg/kg from 0.41kg/kg [21].

3.3 Continuous flame regions of bias PC jets ignition at different initial PCCs

The continuous flame regions of bias PC jets ignition at different initial PCCs are shown in Figure 8. The figure shows that the continuous flame region boundary at different initial PCCs started at an axial distance of 540mm. With increasing initial PCC, the continuous flame region of bias PC jets became gradually concentrated, which means the flame stability became stronger[9]. It can be also found from Figure 8 that the continuous flame regions of bias PC jets leant obviously in the direction of the fuel-rich jet as initial PCCs increased, which is due to the ignition of fuel rich jet in this study being better than that of the fuel-lean jet at a PA velocity of 16 m/s for each initial PCC[9].

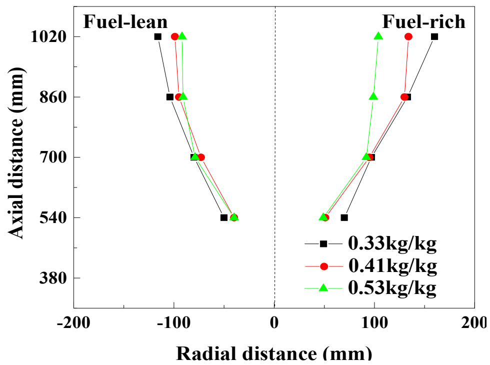

Fig 8 Continuous flame regions at different PCCs

4. CONCLUSIONS

With increasing initial PCC for bias PC jets, the standoff distance gradually decreased; the continuous flame regions became concentrated; the flame stability became stronger, and the ignition characteristics gradually improved. While initial PCC were at 0.33kg/kg and 0.41kg/kg, there was homogeneous-heterogeneous combined ignition mode; while initial PCC increased to 0.53kg/kg, the ignition mode changed to homogeneous ignition mode. For different initial PCCs, the continuous flame region of bias PC jets leant obviously in the direction of the fuel-rich jet.

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