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Cold experimental studies of flow field in the swirling coal combustion device

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Cold experimental studies of flow field in the swirling coal combustion device

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Abstract. In this paper, the influence of different geometric and operation parameters on the flow field in the swirling coal combustion device were studied, like the tuyere positions, the air supply forms and the air velocity, for the particles velocity distribution in the D300 furnace. By comparing the distribution of particles in the four inlet modes of 0 °, 10 °, 16 ° and 22 °, the tangential velocity distribution of particles is more symmetrical along the radial direction under the condition of 0° air inlet. Tangential velocity is smaller, increase the residence time of pulverized coal in the swirling coal combustion device. The residence time of fuel particles also can be prolonged which is beneficial to increase the combustion efficiency of the swirling coal combustion device. And provide the basis for the selection of the swirling coal combustion device in hot experiment.

1. Introduction

The energy demand continues to increase of China, coal as primary energy production accounts for 72.1% (2015), coal as a major fossil fuel and energy still play an extremely important role in China's economic development. However, the exploitation and utilization of coal has also brought many negative impacts on the national economy and people's lives, at the same time the country for environmental protection requirements more stringent [1, 2]. Swirling burner is one of the power-generating devices where fuel combustion or gasification processes occur in a strong eddy flow of gas, with effective mixing and a relatively small combustion chamber in swirling burner. Swirling burner can be used for efficient combustion of coal [3], as well as hazardous waste combustion decomposition treatment, also can be used for metallurgical slag of high temperature restructuring [4]. The main drawback of the swirling burner is that the carbon content in fly ash is 10% ~ 15%, and the NOx emissions are above 1300 mg Nm^{-3} (at 6% O_2 dry). Many researchers have studied the combustion characteristics and NOx emissions. Therefore, to achieve clean burning of coal in our country has a very important significance.

Commonly used coal combustion technology has liquid slagging technology and solid slagging technology, in which solid slag technology with CFB (circulating fluidized bed technology), liquid slagging technology to liquid slagging boiler applications more. Liquid slagging boiler In foreign applications more, there are relatively more mature design and manufacturing experience, and less in the domestic application, the lack of relatively mature design calculation method [3-7]. The research direction of the liquid slagging furnace is mainly focused on the emission reduction of NOx and SO_2 and the improvement of coal combustion efficiency. However, the liquid slagging process causes the combustion reaction and heat transfer process in the furnace to be extremely complicated, and the high temperature molten particles are in the furnace driven by the surface is usually adsorbed on the surface of the slag film, the formation of near-wall combustion or adherent combustion, to the furnace simulation has brought great challenges [8-12].

In this paper, through change the structure of the furnace to form a new type of swirling coal combustion device. On the basis of PIV experiment, the internal flow field characteristics and the three-dimensional velocity distribution characteristics of different cross-section of the new swirling coal combustion device were studied respectively, which provided reference for the hot experiment of the swirling coal combustion device.

2. Model descriptions

2.1. The swirling coal combustion device geometry

The geometry of the swirling coal combustion device used for experimental models in this study is presented in Fig.1a, for Z1 and Z2 measurement station were studied, and four different swirling coal combustion device geometries were studied (Fig.1b), where the angle of the inlet1 and inlet2 were 0°,10°,16°and 22°, respectively.

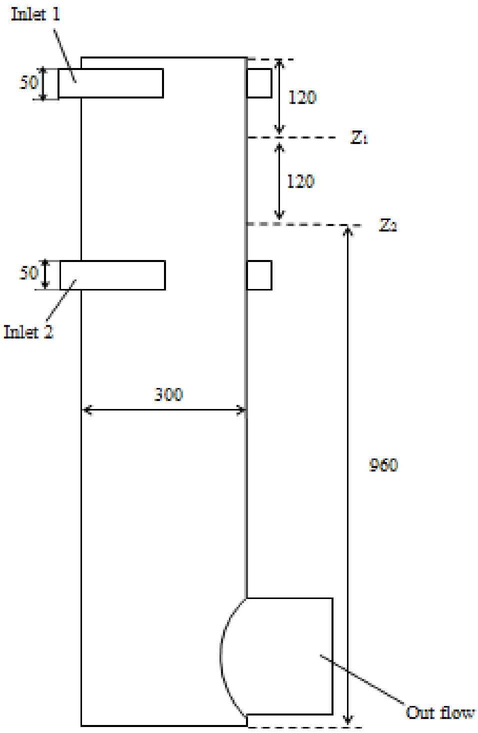


Figure 1a. The schematic diagram of the chamber（unit：mm）

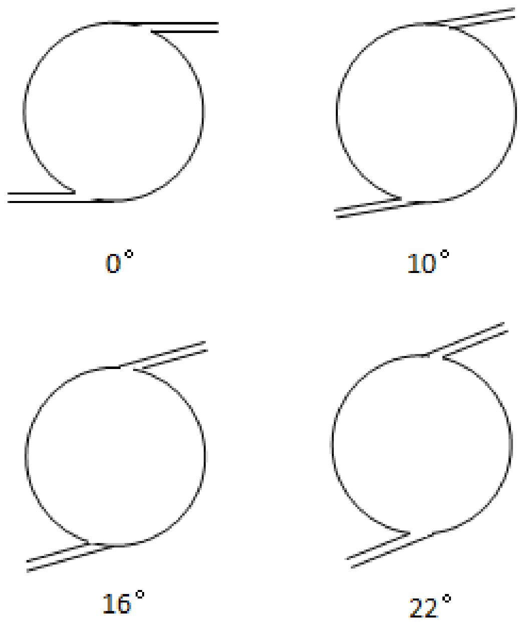


Figure 1b. The angle of the inlet1 and inlet2

2.2. Experimental system

The research is carried out in the self-designed equipment, the experimental device is shown in the Fig. 1, H (Height of combustion chamber) = 1.5 m, D (Inner diameter of combustion chamber) = 0.3 m. Physical experiments were constructed using the structural parameters of table 1. Transparent plexiglass was used as wall materials. In order to reduce errors caused by laser scattering, a couple of orthogonal planes were processed in the outside of transparent model. Two measurement technologies were applied: CCD camera to record the trajectory of tracer particles and PIV measurement to obtain the detailed flow field over a vertical plane passing the swirling chamber center. Figure 2 shows the PIV measurement system, which consists of physical model system and a PIV system. Glass bead

(149um) was used as tracer particles of air particles in the experiment. The trace particles were transported from the primary air inlet to the combustion chamber with air.

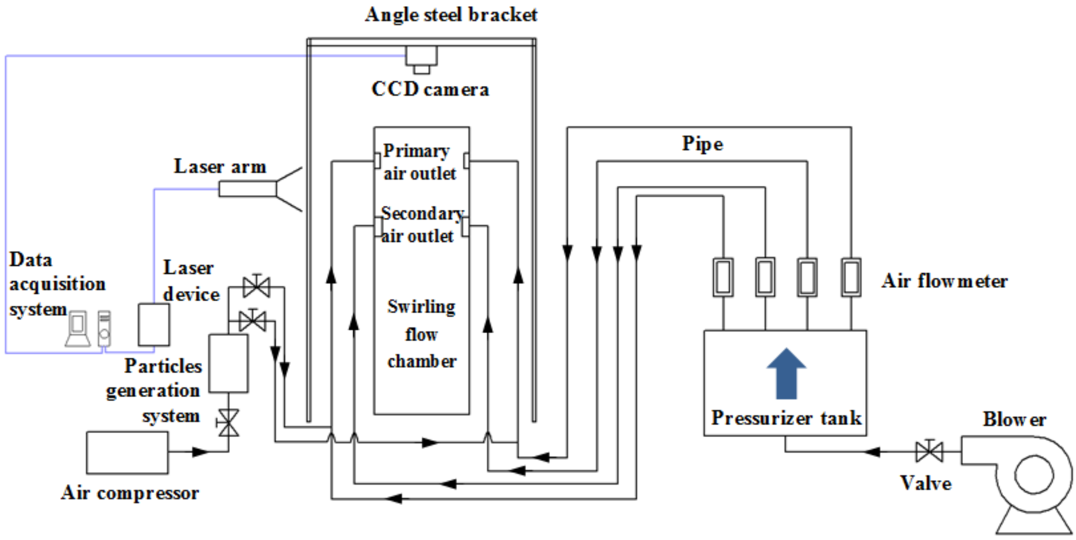


Figure 2. The PIV measurement system

All the structural parameters used in the simulation are listed in table 1, and the operating condition parameters are shown in table 2.

Table 1. The structural parameters of the swirling device

Structural parameter	Value
Diameter of cyclone furnace/mm	300
Size of the inlet1/mm	50×8
Size of the inlet2/mm	50×10
The angle of the inlet1 and inlet2	0°,10°,16°,22°

Table 2. The operation condition parameters in this study

Structural parameter	Blast capacity of inlet1(m^3/h)	Blast capacity of inlet2(m^3/h)
Condition 1	14	96
Condition 2	22	88
Condition 3	22	96

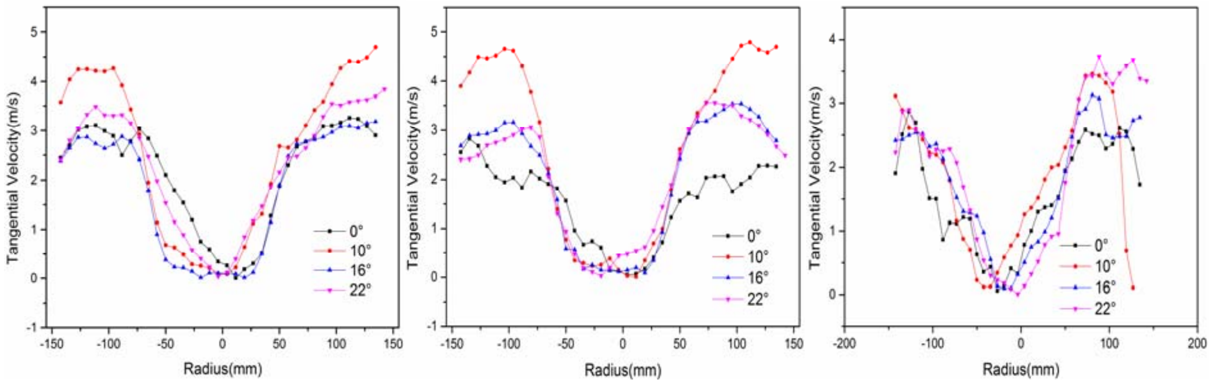
3. Results and discussion

3.1. Velocity profiles

The velocity profiles at different locations were recorded. Two locations were used 120, 240mm from the top of the device. These positions were selected to give a general description. The operation parameters for this section are condition1, condition2 and condition3.

3.1.1. Z1=120mm of different working conditions. In the velocity field of the swirling coal combustion device, the tangential velocity dominate, which is an important factor influencing the distribution of the air flow field. The tangential velocity distribution of 0°,10°,16° and 22° air intake PIV measured values of different cross-sections in the swirling coal combustion device are shown in figure3 and figure4.

Figure3 shows that the contrast of tangential velocities of different inlet angles with the same conditon in the Z1=120mm cross-section.



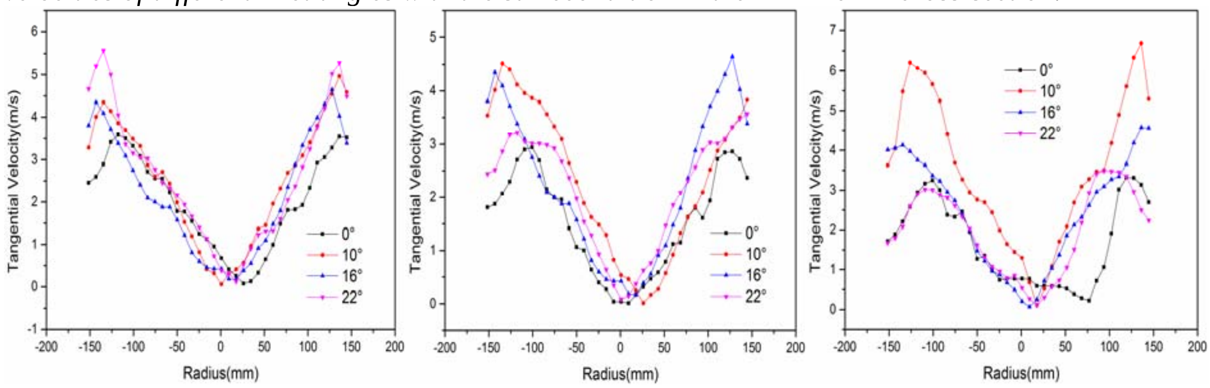
a. condition 1 b. condition 2 c. condition 3

Figure 3. The tangential velocity distribution at the section Z1=120mm of different working conditions

It can be seen that the tangential velocity is radially symmetric in the three conditions, Under the condition 1 and condition 2, the tangential velocity of the glass bead is symmetrical along the radial center (figure3a, 3b), The symmetrical center of the tangential velocity of the glass bead is shifted to the furnace wall under the condition 3 (figure3c).

Under the three conditions, the maximum tangential velocity of particles is 10°of air intake. The minimum tangential velocity of particles is 0°of air intake, on the one hand due to 0° into the air conditions, the glass beads close to the furnace wall into the chamber, glass beads and the furnace wall there is a relatively large friction, resulting in the glass beads tangential velocity is greater Loss. The maximum tangential velocity of the glass bead is 10° under the condition of air inlet. On the one hand, because the friction loss between the glass bead and the furnace wall is small, on the other hand, the influence of the side tuyere is smaller.

3.1.2. Z2=240mm of different working conditions. Figure4 shows that the contrast of tangential velocities of different inlet angles with the samecondition in the Z2=240mm cross-section.

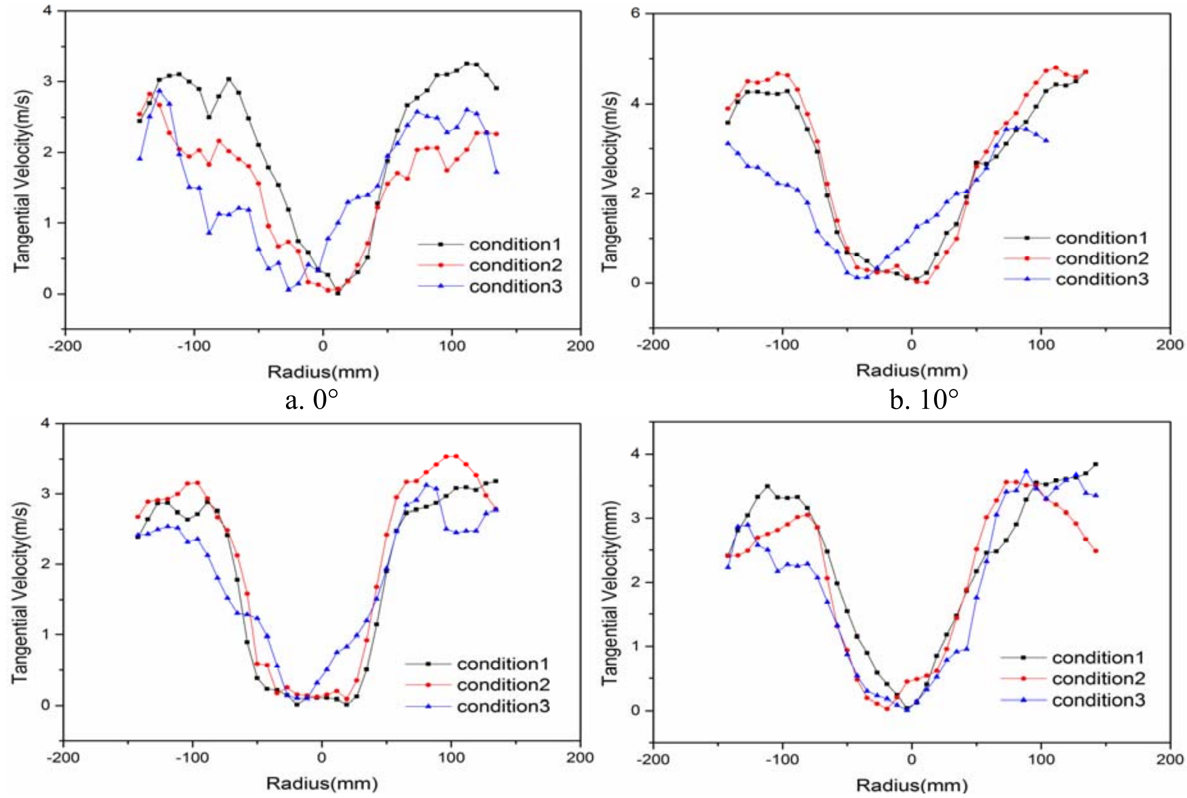


a. condition 1 b. condition 2 c. condition 3

Figure 4. The tangential velocity distribution at the section Z2=240mm of different working conditions

As shown in figure 4, the tangential velocity is still large under the 10° inlet condition, but the tangential velocity difference of particle is not obvious under different inlet angle conditions with figure3, the Z2 cross-section is closer to the secondary air inlet, the secondary tuyere has a greater effect on the tangential velocity of particles under the Z2 cross-section.

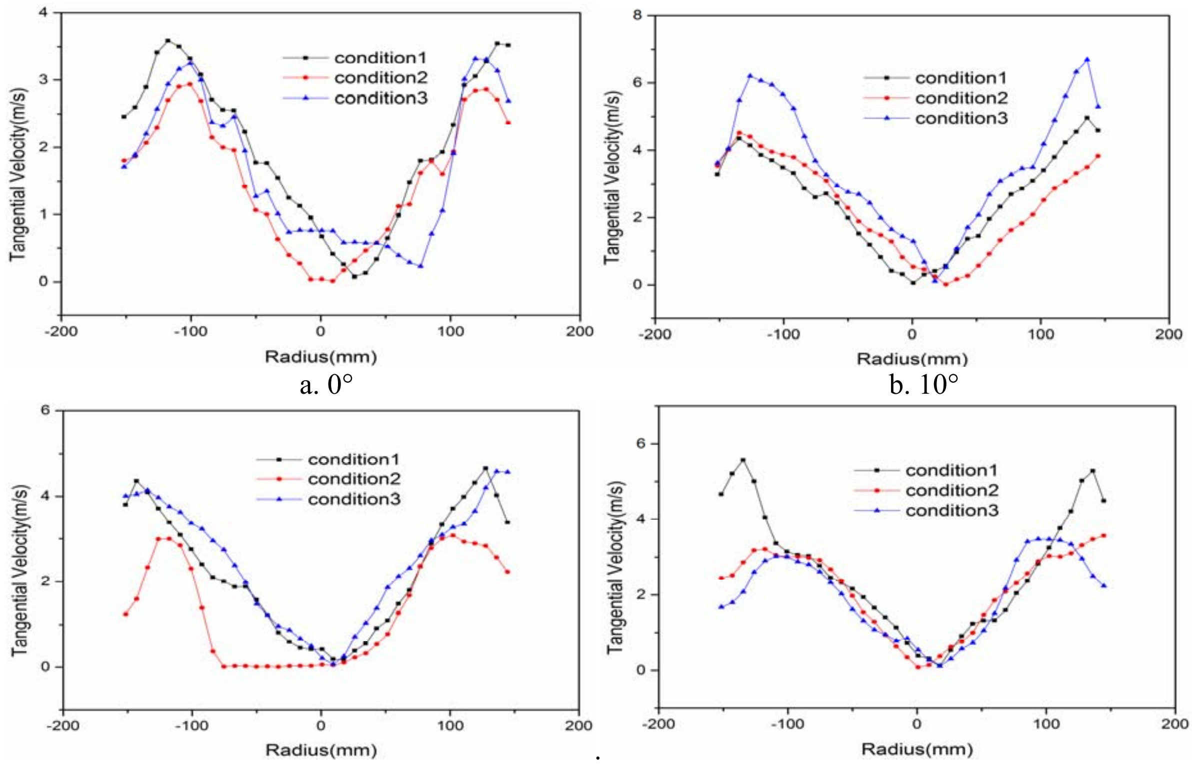
3.1.3. Z1=120mm and Z2=240mm section of different air inlet angle



a. 0° b. 10°

c. 16° d. 22°

Figure 5. The tangential velocity distribution at the section Z1=120mm of different air inlet angle



a. 0° b. 10°

c. 16° d. 22°

Figure 6. The tangential velocity distribution at the section Z2=240mm of different air inlet angle

As can be seen from Figure 5 on the Z1 section, the tangential velocity of the glass bead is larger under the condition 1 and condition2, On the one hand is the second wind speed larger, a greater impact on the primary air speed. On the other hand, the primary air speed is larger, and the formation of strong recirculation in the furnace has a great influence on the tangential velocity of the glass beads. And the tangential velocity distributions are more uniform at 0° and 22° air inlet angle.

As can be seen from figure 6 on the Z2 section, the tangential velocity of the glass beads shows the same trend, the tangential velocity of the glass bead is larger under the condition 2 and condition3, And the tangential velocity distributions are more uniform at 0°, 10°and 22° air inlet angle.

It can be seen from figyre 5 and figure 6 that the tangential velocity of the glass beads in the Z1 and Z2 cross sections is the smallest, which is most favourable for increasing the residence time of the glass beads in the furnace, which is more favourable for efficient combustion of pulverized coal in the hot experiment.

4. Conclusions

The tangential velocity is radially symmetric in the three conditions, under the condition1, condition2 and condition 3, the tangential velocity of the glass bead is symmetrical along the radial center, and the tangential velocity distributions are more uniform at 0°, 10° and 22° air inlet angle. The tangential velocity of the glass beads in the Z1 and Z2 cross sections is the smallest, which is most favourable for increasing the residence time of the glass beads in the furnace, which is more favourable for efficient combustion of pulverized coal in the hot experiment.

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