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Research paper

Combined control of secondary air flaring angle of burner and air distribution for opposed-firing coal combustion

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HIGHLIGHTS

- We propose a novel combustion adjustment method with burner flaring angle.
- We combine burner flaring angle with air distribution to control combustion.
- The effect of combustion adjustment on temperature distribution is studied.
- The burnout and NO_x emission are improved through combination adjustment.

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ABSTRACT

A novel swirl burner with adjustable inner secondary air flaring angle β is proposed and tested in an opposed fired pilot-scale furnace. The influences of five different flaring angles (β = 11.4/17.1/26/31.7/35.5) are studied on combustion and emissions under different air distributions. Two different rank coals are used. Changing β with air distribution helps coal ignition and promotes burning temperature level. Low-rank coal requires larger β for ignition and burning fiercely than high-rank coal. Enlarging β to 31.7° helps to decrease CO emission effectively. The specific β corresponding to a certain air distribution can limit NO_x emission further. The high burnout of two coals corresponds to different β of burner. Inner secondary air flaring angle variation, combining with air distribution adjustment, can improve coal adaption, and help burning more effectively and cleaning.

1. Introduction

Coal combustion plays an important role in world energy consumption. Especially in China, coal constitutes approximately 60% of primary energy resources and is the dominant fuel in power plants. The coal-fired power generation still accounts for above 75% proportion of total installed capacity in China [1]. At present, wall fired, tangential-fired and W-flame fired are the three most popular combustion technologies applied in power plants [2–10]. Wall fired boiler is widely used because of its flame organization independence, unlimited boiler shape and little gas temperature deviation in the horizontal flue gas pass. However, flame stability at low load and NO_x emissions are still the main concerns in design and operation [11]. Novel swirl coal burner technology presents an efficient method to solve these problems by enhancing ignition and staged combustion. Swirl burner has become the focus of researchers in recent years. A. Giannadakis [12] investigated a swirling jet under the influence of a coaxial flow and discussed complex bubble in the flow field. M.A. Nettleton [13] discussed the influence of swirl angles on flame stability in pilot-scale plant. Šarlej demonstrated an application of computational fluid dynamics in burner design and optimization [14]. Zhou [4] researched the influence of primary air pipe of a low NO_x swirl burner on combustion characteristic. Jing [15] operated experimental study on outer secondary air vane angle. Li [11] proposed a new low-NO_x burner technology with centrally fuel rich coal combustion burner. These literatures focused on the burner structure modified and innovations. Air distribution adjustment is also an effective way for burner to improve or change combustion conditions in power plant. Anil Purimetla [16] performed computational studies on the secondary air flow of the burners to assure proper balance and optimization. Jing [3] studied the effect of primary air ratio on combustion and NO_x emissions. A.S. Veríssimo [17] investigated the inlet air velocity importance on

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Nomenclature

IPA	inner primary air
OPA	outer primary air
ISA	inner secondary air
OSA	outer secondary air

Symbols

a	depth of furnace (m)
ρ	density (kg/m^3)
u	axial velocity (m/s)
x, y, z	depth, width and height coordinate of the furnace (m)
X, Y, Z	dimensionless depth, width and height of the furnace (-)
t	gas temperature (°C)
β	inner secondary air flaring angle (°)
w	mass fraction (%)
ψ	char burnout

Subscripts

$1/2,3/4$	inner/outer primary air, inner/outer secondary air
k	input coal
x	char sample
opt	optimization

flameless combustion establishment. A. González-Cencerrado [18] studied the pulverized fuel flame characteristic under different swirl numbers. In recent years, the effect of coal concentration variation in primary air of burner on NO_x reduction is discussed [19,20]. However, the study on the flaring spout, which is commonly used in the swirl burner and has significant impact on combustion characteristics, is little reported.

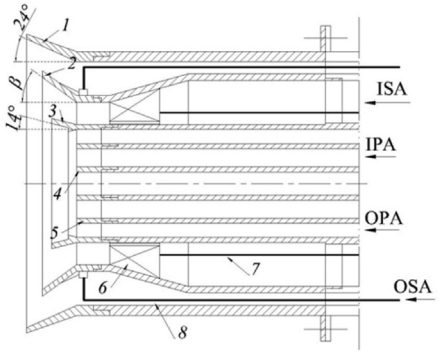
In this work, a novel swirl burner with adjustable inner secondary air (ISA) flaring based on dual-register burner structure is proposed. The combustion technology of integrating ISA flaring angle modulation and the traditional air distribution adjustment is explored through combustion experiment. From the result we try to understand how the flaring angle and air distribution affect coal combustion. Combustion efficiency and pollution emission are also comprehensively discussed in this paper.

2. Novel burner and experimental setup

Flaring angle of swirl burner is proved to influence reflux and flow characteristic outside the spout [21,22]. This novel burner proposed in our work replaces the traditional stationary flaring with adjustable flaring composed of circumferential stacked steel sheets, which is shown in Fig. 1. It realizes real time adjustment of the flaring angle to satisfy different combustion needs.

There are four layers in the burner to supply combustion air, which are inner/outer primary air and inner/outer secondary air, separately. Only inner secondary air is rotary jet caused by axial swirl vanes. The adjustable ISA flaring is comprised of 24 partial overlapping multi-flakelets circumferential distribution on the end of inner secondary air straight pipe. Pins are used to connect the adjustable flaring and straight pipe so as to rotate the flakelets and vary flaring angle. Each flakelet fixes one linkage on the back with pin seal. All the linkages are connected by a lantern ring. Two steel rods are separately fixed on the lantern ring symmetrically. The flaring angle β can be changed through pulling or pushing the steel rods.

(a) Burner spouts of three different ISA flaring angles



1. outer secondary air flaring; 2.adjustable inner secondary air flaring; 3.outer primary air; 4.center air pipe; 5.inner primary air pipe; 6.swirl vanes; 7.steels rods of swirl vane; 8.steel rods of adjustable ISA flaring

(b) Burner structure

Fig. 1. Novel swirl burner with adjustable inner secondary air flared pipe.