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The Development of High Performance Flame Stability(HPFS) Tangential Coal-Fired Burner

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ABSTRACT

This report presents a study of the development of an advanced coal nozzle used in burners to reduce unburned carbon (UBC) in a tangential coal-fired boiler. To understand the mechanism of UBC reduction, experiments using conventional burners were carried out to evaluate the effects of air injection velocity, coal fineness and over fired air (OFA) on combustion efficiency. It was confirmed that ignition of pulverized coal particles close to the burner is helpful toward the complete burn of residual carbon in fly ash. These efforts indicated the additional results that UBC was strongly dependent on the primary air velocity and coal fineness; especially that UBC dramatically decreased when the weight fraction of pulverized coal under 75 μm was over 85 %.

New coal nozzles, modified from conventional nozzles, were prepared and tested to improve the combustion efficiency. Some of these nozzles offered relatively lower unburned carbon than those of conventional burners and are referred to as HPFS (High Performance Flame Stability) coal nozzles.

Key Words : Tangential Coal-Fired Burner, Ignition, Flame Stability, Unburned Carbon, HPFS(High Performance & Flame Stability)

1. Introduction

Coal fuels used in power plants in Korea have been very diverse because they are all imported from various coal mine throughout the world and because, in more recent circumstances, the international coal market is unstable. Moreover, coal fuels include low-grade coals that are not fit for combustion in pulverized coal fired boilers. Despite these circumstances, customers are requiring a combustion system that reduces UBC in fly ash, has high boiler efficiency and satisfies the environment regulations in a low excess air atmosphere. It is difficult for conventional coal burners to meet the above requirements and overcome fuel flexibility.

This paper presents the study of burner development in tangentially fired boilers to reduce unburned carbon in fly ash. To accomplish this, Doosan conducted an experiment to develop a concept for low loss combustion using conventional coal nozzles, both standard and wide range. As a result, these efforts confirmed that a reduction of UBC in fly ash could be achieved by ignition forming the stable flame as soon as coal particles were injected from nozzles. The ignition of pulverized coal strongly depends on the volatile matter of fuel, particle size, air injection velocity and geometry of coal nozzle[1-4].

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The study focused on determining the configuration of a coal burner that creates the source of ignition energy in the outlet of coal nozzle. The suitable configurations of coal nozzles, referred to as HPFS(High Performance Flame Stability),were developed in this study via combustion tests conducted with the various types of coal nozzles. These advanced coal nozzles for tangential coal-fired burners had external flame stabilizers, and were modified from conventional nozzles with or without an internal bluff body. These nozzles were more effective in increasing combustion efficiency than burners with conventional nozzles.

2. Test Facility and Experimental Condition

Figure 1 shows the single tangential coal-fired burner used in the combustion test. This burner has a coal nozzle and two secondary air(SA) nozzles above and below the coal nozzle. The burner wind box is equipped with an air damper to control airflow rate in each air path.

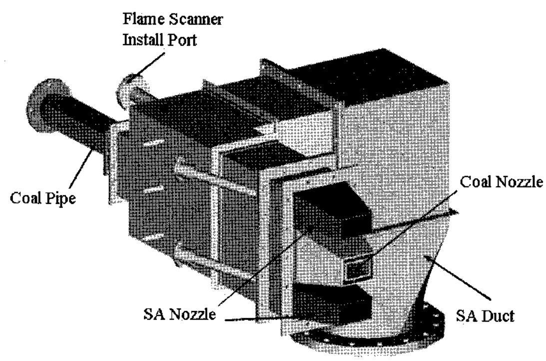
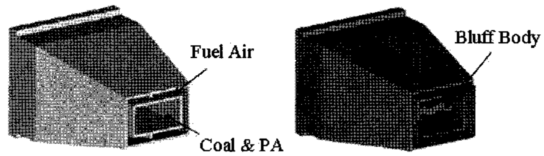


Fig. 1 Configuration of single tangential coal fired burner.

The test burner was installed in a cylindrical and horizontal water-cooled furnace, which had been designed to have a thermal capacity of 3.0 MW. The inner diameter of this furnace was 2.0 m and the length was 6.0 m. Right and left sides of furnace have two-staged air ports (OFA) with 0.5 m interval.

Figure 2 shows the configurations of the conventional coal nozzles used in the test to determine the reduction mechanism of combustion loss. Standard coal nozzles (STD) have been widely used in burning good combustible bituminous coals, and wide range coal nozzles (WR) have been applied to burn low-grade coal and increase turn down ratio. The later has a configuration suitable to enhance flame stability because it creates a low velocity recirculation zone behind the bluff body. The heat of high temperature gas as an ignition source is retained by this recirculation zone[5, 6].

To understand the effects of primary air velocity on ignition and UBC in fly ash, each nozzle type (STD and WR) shown in Fig. 2, were individually designed in two models with different injection velocities of 30.1 m/s and 21.4 m/s. These were identified as STD1, STD2, WR1 and WR2, respectively.



a) STD b) WR

Fig. 2 Configurations of conventional coal nozzles.

Table 1 gives the compositions of test coals. The coal consumption rate was 250 kg/hr and it was heated to 65°C at the burner inlet and transported into the coal nozzle by primary air. Pulverized coal injected from the coal nozzle was mixed with secondary air, which was kept at a constant temperature of 250°C by an air heater.

The primary airflow rate was twice as large as the coal flow rate and the secondary airflow was controlled to maintain 3.5 % O_2 at the furnace outlet. Pulverized coal fineness, controlled by the pilot pulverizer with the advanced dynamic classifier, were 71.2, 86 and 92 wt% passing a 200 mesh. The location of OFA ports was 3.5 m distant from burner outlet and OFA flow rate was 0~40 % of total combustion airflow rate.

The flame shape of the test burner was taken by endoscope installed at the sidewall of the furnace. The concentrations of oxygen and NOx in the flue gas at the furnace outlet were measured by gas analyzer (Xentra 4100, paramagnetic & infrared type) and NOx analyzer (CAI 300-CLD, chemiluminescence type), respectively. UBC in fly ash, sampled by the iso-kinetic probe at the furnace outlet, was analyzed by TGA 701(thermo-gravimetric analyzer) in compliance with ASTM.

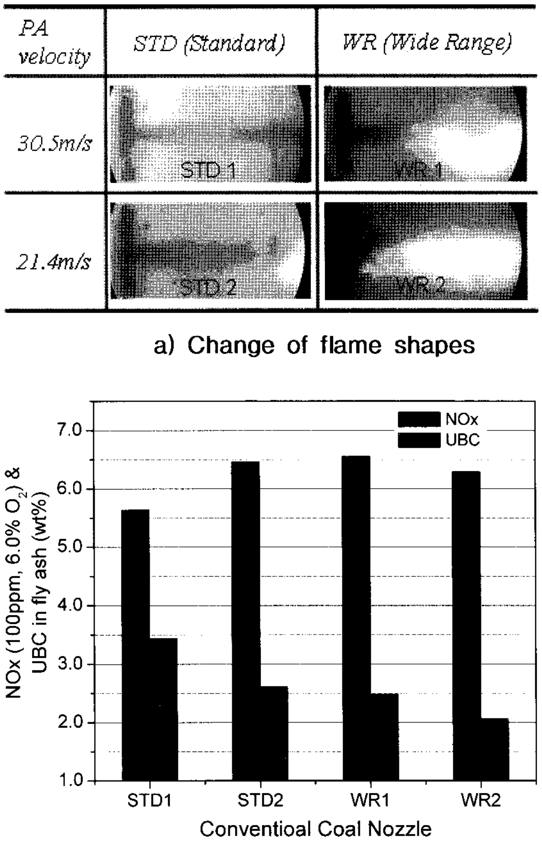
Table 1 Analysis data of test coal

Proximate analysis(Air dry basis)		
Moisture	wt%	6.73
Ash	wt%	7.07
Volatile Matter	wt%	33.82
Fixed Carbon	wt%	52.38
Sulfur	wt%	0.33
HHV	kcal/kg	6773.80
Ultimate analysis(dry basis)		
Carbon	wt%	79.70
Hydrogen	wt%	4.69
Nitrogen	wt%	1.20
Combustible sulfur	wt%	0.25
Ash	wt%	7.58
Oxygen	wt%	6.61

3. Test Results

3.1 The effect of primary air velocity and bluff body

Figure 3-a) shows flame shapes with change of primary air velocities for coal fineness under 71.2 wt%. The ignition of coal particles in STD1 and WR1 occurred further downstream of the burner outlet than that in STD2 and WR2. The ignition point in both WR nozzles is relatively close to the burner outlet in comparison with STD nozzles. These confirm that primary air velocity and bluff body affects early ignition at the burner outlet. Fig. 3-b) shows the NOx emission and UBC of STD and WR coal nozzles. NOx increased with a decrease of primary air velocity and the existence of bluff body, but the trend of UBC was to the contrary. These results indicate that the closer the ignition point is to the burner exit, the lower is UBC.



a) Change of flame shapes

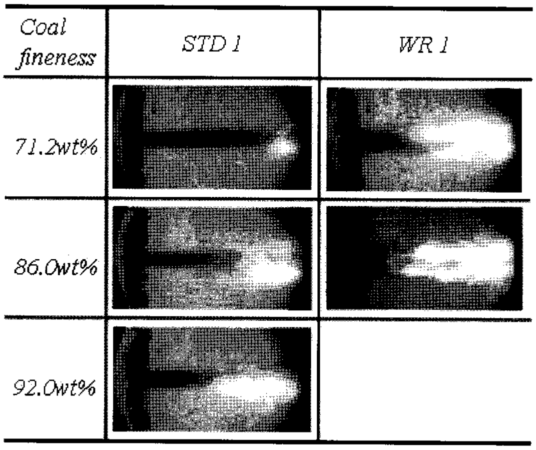
b) NOx and UBC

Fig. 3 The test results with primary air velocities.

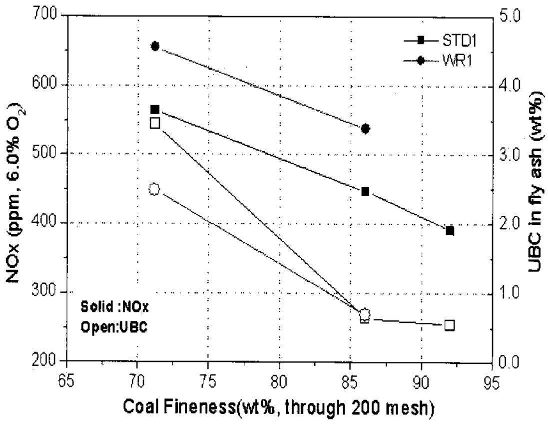
3.2 The effect of pulverized coal fineness

Figure 4-a) shows the flame shapes formed in STD1 and WR1 nozzles with change of coal particle size. The ignition point distance decreased with an increase in coal fineness because the surface area of fuel increased. The ignition point of WR1 is the shorter of the two nozzles under all particle fineness due to the effect of bluff body described in Fig. 3.

The variation of NOx and UBC with the particle fineness is shown in Fig. 4-b). Both NOx emission and UBC decreased with an increase in coal fineness. UBC decreased remarkably when coal fineness changed from 70 % to 86 %, but the rate is nearly steady after this range. The steady region of UBC

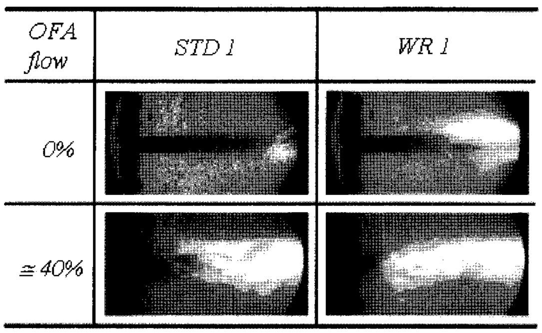


a) Change of flame shapes

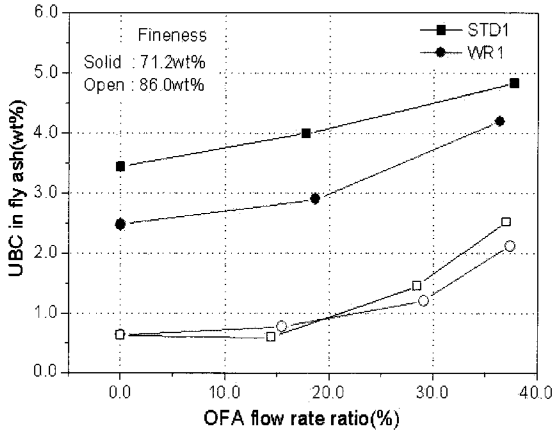


b) NOx and UBC

Fig. 4 The test results with pulverized coalfineness.



a) Change of flame shapes



b) NOx and UBC

Fig. 5 The test results with OFA flow rate ratio.

seems to be independent of nozzle configuration with or without bluff body. This confirms that the bluff body affects particle ignition, but coal fineness affects the total burning process of coal including coal pyrolysis, ignition, volatile and char combustion[7].

3.3 The effect of the existence of OFA

The flame shapes with the change of OFA flow rate are shown in Fig. 5-a). The ignition point moved toward the burner with increase of OFA flow rate, i.e. decrease of secondary air velocity. This implies that the ignition point is affected by the secondary airflow velocity as well as primary air velocity.

Figure 5-b) shows UBC with OFA flow rate ratio defined as the percent of OFA flow rate per total air flow rate. These data were obtained under 71.2 and 86.0 wt% of coal fineness. WR has an advantage to reduce UBC when coarse particles are burned, but UBC is independent of nozzle shapes in the combustion of fine particles with OFA as mentioned above. This means that a greater reduction of UBC with coarse particles can be achieved by nozzles modified with flame stabilizers, which are able to ignite the particles just at the burner exit.

3.4 Development of advanced coal nozzle

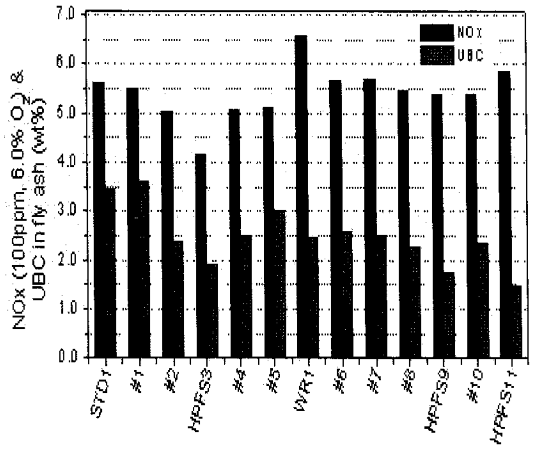
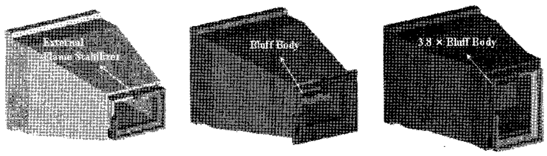


Fig. 6 NOx and UBC with advanced coal nozzles based on STD and WR type.

Through the previously described experiments, it was determined that an ignition point located as close as possible tothe burner is better to reduce UBC. The important parameters of ignition are primary/secondary injection velocity, coal fineness and bluff body of coal nozzle. Air injection velocity and coal fineness is determined by coal quality and may be changed during optimizing combustion process in pulverized coal-fired boiler. Therefore, we focused on the development of advanced coal nozzle equipped with flame stabilizers for enhancement of coal burnout.

Eleven test nozzles were prepared and tested to determine the suitable type of nozzle for UBC reduction. Fig. 6 shows the test results of these which have external flame stabilizers based on STD and WR. It is confirmed that HPFS3, HPFS9 and HPFS11 are the most effective in meeting the purpose of this study. Their configuration is shown in Fig. 7. Bluff body height of HPFS11 is 3.8 times of that of HPFS9. While HPFS3 has only the external flame stabilizer, HPFS9 and HPFS11 have internal and external bluff bodies. These three HPFS nozzles reduce UBC by over 46 % compared with STD1 at 71.2 % coal fineness. In addition, HPFS3 has the lowest NOx emission.



a) HPFS3 b) HPFS9 c) HPFS11

Fig. 7 Configuration of HPFS coal nozzles.

4. Summary

To develop an advanced coal nozzle for burners to reduce unburned carbon (UBC) in fly ash from tangential coal-fired boilers, Doosan carried out experiments to evaluate the effects of air injection velocity, coal fineness and over fired air (OFA) on combustion efficiency. It was determined that the ignition point is a key parameter, and that UBC is lower when the ignition point is close to the burner exit.

Advanced coal nozzles, referred to as HPFS nozzles, were developed which deliver UBC reductions of more than 46% compared to standard nozzles with coarse coal particles.

Acknowledgement

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