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Experimental measurements of a gas–solid jet downstream of a fuel-rich/lean burner with a collision-block-type concentrator

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Abstract

The mixing mechanisms in the gas–solid two-phase fuel-rich/lean jet from a burner with a collision-type coal concentrator has been experimentally investigated using a fiber optic measurement system in a continuous-two-phase-flow loop of internal diameter 150 mm. The local solid concentration and particle size distribution were measured to investigate the mixing performance of the parallel fuel-rich and fuel-lean streams, and also the process of development of the fuel-rich/lean jet. The measurement results indicated that the concentration ratio between the fuel-rich and fuel-lean streams changes greatly with the height of the collision block. The fuel-rich and fuel-lean streams do not mix together soon after leaving the burner; this leads to better ignition and combustion characteristics of the pulverized coal compared with an ordinary burner. A local zone of high fuel concentration can be achieved at the fuel-rich side, resulting in staged combustion, to control NO_x emissions. A deviation between the jet direction and the nozzle axis was found, resulting from the velocity difference between the fuel-rich and fuel-lean streams, and a larger deviation in the profile of the solid phase was also observed. Such a deviation of the high-concentration zone is favorable for flame stability and NO_x emission reduction.

Keywords: Gas–solid flow; Concentration measurement; Fiber optic sensor; Fuel-rich/lean burner

1. Introduction

Coal-fired power stations throughout the world are now subject to stringent pollution regulations and suffer penalties if the polluting emissions exceed acceptable limits. In recent years, a novel pulverized-coal combustion technology called the horizontal fuel-rich/lean burner has been developed and applied widely in power station boilers in China, with the benefits of burning low-volatile coal more efficiently and decreasing the NO_x emissions [1].

When a horizontal fuel-rich/lean burner is employed in a tangentially fired boiler, a fuel concentrator needs to be employed in the fuel-conveying line to divide the fuel/air mixture into a fuel-rich and a fuel-lean stream with different solid concentrations. The fuel-rich stream is injected on the side facing the high-temperature flame; it serves as a powerful

Table 1
The operational parameters of the industrial and laboratory burner

	Gas velocity at nozzle exit (m/s)	Exit area (mm × mm)	Air temperature (°C)	Atmospheric pressure (bar)	Particle mean diameter (μm)
Industrial	23	433 × 325	268	0.848	40
Laboratory	14	160 × 120	20	1.0	14.3

Table 2
Laboratory experimental cases

Case	Collision block height (mm)	Relative collision block height	Gas velocity at nozzle exit(m/s)	Particle mean diameter (μm)
1	40	0.25	14	14.3
2	50	0.3125	14	14.3
3	60	0.375	14	14.3

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Table 3
Comparison of the dimensionless numbers for industrial and laboratory scales

		Industrial scale	Laboratory scale
Reynolds	$Re=\dfrac{\rho UD}{\mu}$	1.687×10^5	1.518×10^5
Froude	$Fr=\dfrac{U}{\sqrt{Dg}}$	12.53	12.53
Stokes	$St=\rho_p d_p^2 U/(18D\mu)$	0.197	0.172
Temperature (°C)	T	268	20
Gas velocity in the pipe (m/s)	U	25	15.2
Atmospheric pressure (bar)	P	0.848	1.0
Particle density (kg/m^3)	ρ_p	1200	2700
Particle mean diameter (µm)	d_p	40	14.3
Internal pipe diameter (mm)	D	406	150

stabilizer and ensures flame stability in the furnace. Fuel-lean nozzles are installed between the fuel-rich nozzles and the waterwall. Because of the lean fuel concentration in the fuel-lean stream, oxidizing zones can be achieved near the waterwall. The ash fusion temperature is highly related to the atmosphere of the environment, and the oxidizing atmosphere results in a high ash fusion temperature, leading to resistance of the furnace against slagging and fouling. In addition, corrosion of the waterwall tube can be reduced in an oxidizing atmosphere. Because nonstoichiometric combustion occurs in the cross-section of the furnace under fuel-rich/lean combustion conditions, the NO_x concentration in the emission can also be reduced, as verified by field data [1,2].

The fuel-rich and fuel-lean streams have a large difference in fuel concentration, whereas the velocities of the two streams are kept almost the same to meet the requirements of pneumatic transmission. In the conventional primary air of a pulverized-coal burner, the mass ratio of the fuel/air mixture in the pneumatic pipe is normally about 0.3–0.6 kg (coal)/kg (air), but the optimum ratio for low-volatile coals may be 0.6–1.4 kg (coal)/kg (air) as a result of the need to obtain stable ignition [2]. A high concentration combustion of pulverized coal can be achieved downstream of the fuel-rich nozzle when a fuel concentrator of high bias degree is employed in the fuel transport line.

Various means have been adopted to separate the fuel/air mixture [1], such as louver-type, collision-block-type, and bend-

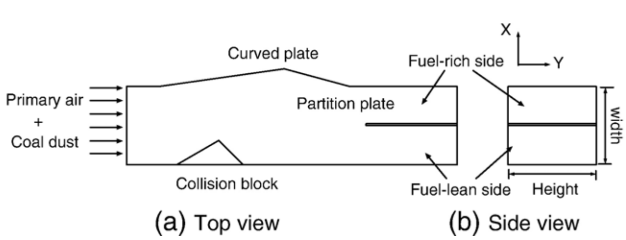

Fig. 1. Sketch of the collision block type fuel rich/lean burner.

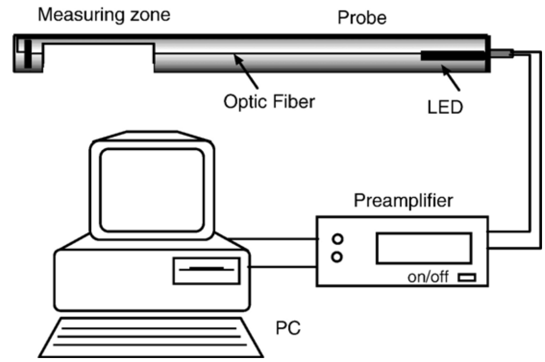

Fig. 2. Fiber optic measurement system.

type burners. In the work described here, the investigation is focused on a collision-block-type fuel-rich/lean burner. As shown in Fig. 1, the collision block diverts the primary airflow and makes the pulverized coal particles rebound from the block surface, thus changing their direction. The coal particles are then carried by the flow to be concentrated on the fuel-rich side over the central partition plate, and a fuel-lean pulverized-coal flow is obtained on the other side beside the partition plate. The concentration ratio between the fuel-rich side and the fuel-lean side can be regulated continuously by adjusting the height of the collision block.

The jet flow injected from a horizontal fuel-rich/lean burner consists of two parallel streams with different solid concentrations. Because the location of the burner is restricted to the corner of the furnace, the two parallel streams are always adjacent, with only a thin partition plate located at the center of

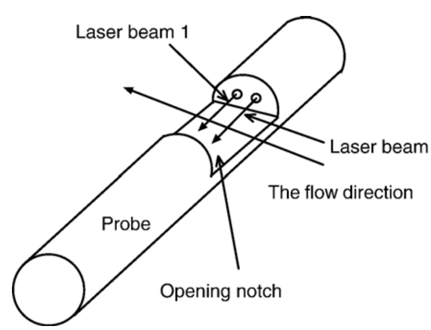

Fig. 3. Sketch of the fiber optic probe.

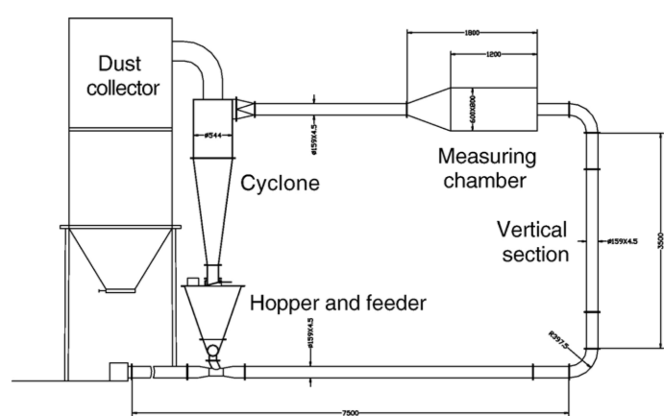

Fig. 4. Sketch of laboratory facility.