한국연소학회지, Vol.11, No.4, pp.22-26(2006)

석탄연소보일러 개조공사에 적용된 저NOx 미분탄 버너의 성능 평가

김상현*† · 송시홍* · 김혁제* · 김혁필*

Performance Evaluation of Low NOx Pulverized Coal Burner Applied in Coal Fired Boiler Refurbishment Project

Sang-Hyeun Kim*†, Si-Hong Song*, Hyuk-Je Kim*, Hyeok-Pil Kim*

ABSTRACT

To meet the environmental requirements, Doosan Heavy Industries & Construction Co., Ltd. (Doosan) had developed low NOx pulverized coal burner and it was applied to boiler retrofit project, 130 ton/hr coal fired co-generation boiler, in 2003. NOx emissionand unburned carbon (UBC) in fly ash were measured during the commissioning tests. In this paper, the operation results of low NOx pulverized coal burner installed in 130 ton/hr coal fired boiler are presented. Burners emitted 160 ppm (@6 % O_2 basis) NOx and 3 % UBC with Chinacoal containing 0.86 % fuel nitrogen. And also it was shown that NOx emission rate of low NOx pulverized coal burner is linearly increased with fuel-nitrogen fraction of coal

1. 서 론

The cogeneration plant of HUVIS Co., Ltd., built in 1987, is a 100 kg/cm^2, 520°C drum-type boiler capable of producing 130 ton/hr steam. The original combustion system of HUVIS′ boiler was designed to burncoal and heavy oil; however, coal operation was suspended for frequent troubles in pulverizer eventually and only heavy oil was used to produce steam.

As the production cost of steam through heavy oil has increased, HUVIS has determined to repair coal combustion system, including coal burner, pulverizer, coal handling and ash removal system. Doosan Heavy Industries & Construction Co., Ltd. (Doosan) has supplied the coal firing system including low NOx burners in 2003.

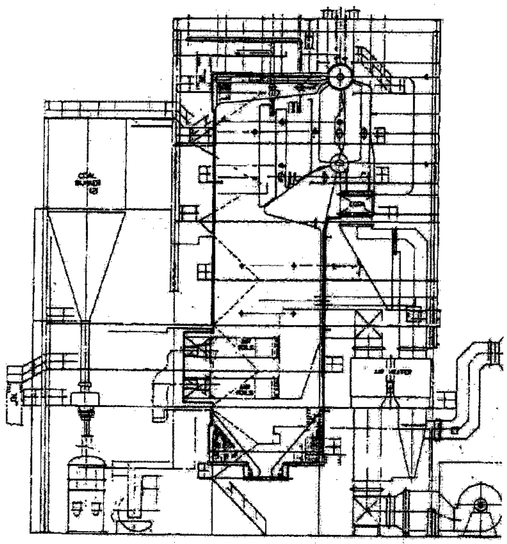


Fig. 1 130 ton/hr co-generation boiler

* 두산중공업

† Corresponding author, sanghyeum.kim@doosan.com

The guarantee value of the supplied coal burner is 250 ppm (@6 % O_2) NOx and 8 % UBC in coal firing condition. Alsothe capability of co-firing of coal and heavy oil should be guaranteed. In addition Doosan had to consider HUVIS's operational requirements such as frequent change of coaland wide range of coal rank.

To meet the NOx and UBC guarantee, low NOx coal burners and pulverizers equipped with dynamic classifier were adopted to this retrofit project. And to correspond to various types of coals, additional OFA ports were installed on top of the previous OFA ports.

This paper presents the operation results of low NOx coal burner according to the operating conditions coal types on a long term basis.

2. Low NOx Pulverized Coal Burner

The low NOx pulverized coal burner developed by Doosan realizes fuel staging and air staging[1,2,3] simultaneously, thereby significantly reducing NOx production in the combustion process of pulverized coal.

To develop the low NOx pulverized coal burner, combustion experiments employing pilot scale test facilities and CFD were utilized.

In order to reinforce the flame stability, secondary and tertiary air flow passage were optimized and local fuel staging is realized by installing control devices in coal injection nozzle.

The shape of low NOx pulverized coal burner, integrating combustion technology and optimizing flow passage, thereby minimizing NOx production, is as shown in Fig. 2. The coal nozzle includes a patented particle erosion prevention and concentration control device. The combustion air is separately supplied to the flame zone through secondary and tertiary air nozzle. Moreover, to enhance the flame stability, the swirlers are equipped in each passage to generate rotating flow in secondary and tertiary air[4-5].

The burners at the site are as shown in Picture 1. The capacity per burner is a 4000 kg/hr, and total fuel consumption rate is 16,000 kg/hr at MCR condition.

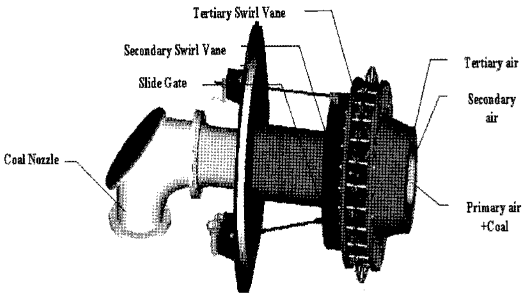
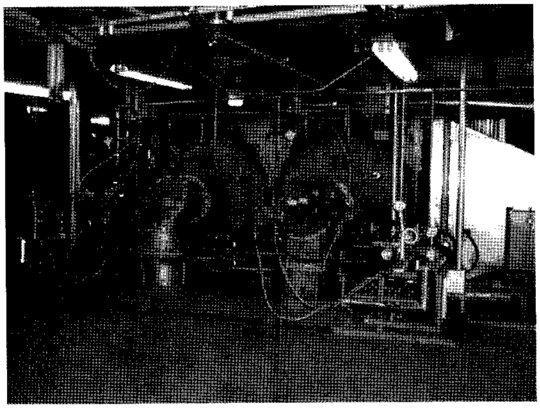


Fig .2 Configuration of Low NOx Burner



Picture 1 Photograph of Installed Burners

3. Performance Test and Results

3.1 Test Coal and Measuring Equipment

There are many aspects in the performance evaluation of the low NOx pulverized coal burner, but the combustion performance related to NOx and UBC is employed in this study. The coal used for performance evaluation was one of the bituminous coals, and its fuel analysis data are shown in the Table 1.

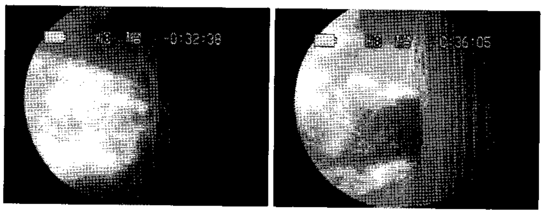
Table 1 Coal Analysis

Proximate Analysis (wt%)		Ultimate Analysis (wt%)	
Moisture	7.18	C	76.30
Ash	8.33	H	4.63
Volatiles	31.71	N	0.86
FC	52.78	S	0.41
Total	100.00	Ash	8.97
		O_2	8.83
HHV(kcal/kg)	6570	Total	100

In order to evaluate the performance of the burner, flue gas and ash particle sampling probe was installed in economizer outlet for measurement of flue gas components and UBC. The instrument employed in flue gas analysis was TESTO 350 XL, which was capable of analyzing O_2, CO, CO_2, and NOx of flue gas in real-time. The UBC was analyzed from the collected fly ash. In addition, the photographs of the flame shape were taken by endoscope and image recording system.

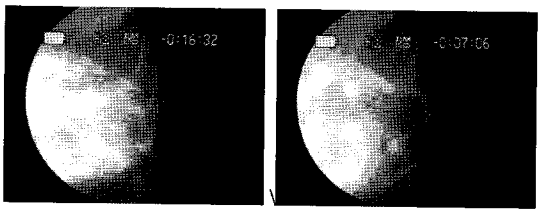
3.2 Flame Shape

The flame shape according to the load and the amount of OFA flow was investigated. There was no drastic difference in appearance of the flame due to the change of load or OFA flow ratio. As shown in Picture 2, the appearance of the flame was not varied with the load; but, in Picture 3, increase in OFA flow ratio generated dark unburned gas around the flame. This seems to be a phenomenon caused by the incomplete combustion due to the decreased air quantity in burner zone.



(a) 88% load (b) 100% load

Picture 2 Flame Shape with Boiler Load



(a) OFA/TCA= 9.3 % (b) OFA/TCA= 13.9%

Picture 3 Flame Shape with OFA Flow

3.3 NOx and UBC characteristics

Figure 3 shows NOx and UBC emission characteristics according to the load change of the boiler in combustion tuning process. As a result, with a constant amount of total combustion air, increase of the boiler load dramatically increases NOx and decreases UBC.

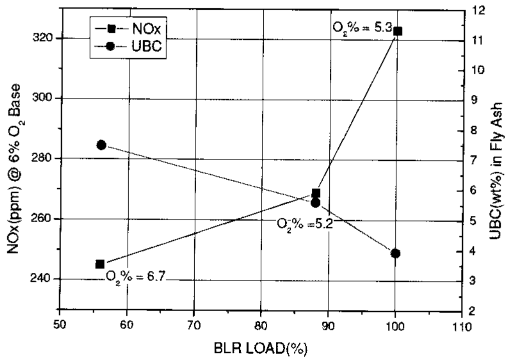


Fig. 3 Variation of NOx, UBC with boiler Load in combustion tuning process

Generally, it is known that in a normal operation of coal boiler, NOx descends with increase of load in the range below a certain load, and then it gradually ascends with increase of load. This trend is strongly dependent on the excess air rate and thermal input with the boiler load.

The discrepancy between the test result and the general trend was caused by the difference in operating modes. Despite the increase in load, the excess air rate was not reduced and the measurement under 50% or less load was not undertaken; a simple comparison is not feasible. However, the increase of NOx according to the load increase resulted from temperature rise in the furnace and abundant oxygen.

Figure 4 shows NOx emission under the variation of excess air at the maximum load of the boiler. In this case, the amount of coal flow was constantly maintained. As widely known, under the condition of abundant oxygen, NOx production tends to increase and UBC decrease. Therefore it can be concluded that lowering excess air in high load will decrease the NOx emission.

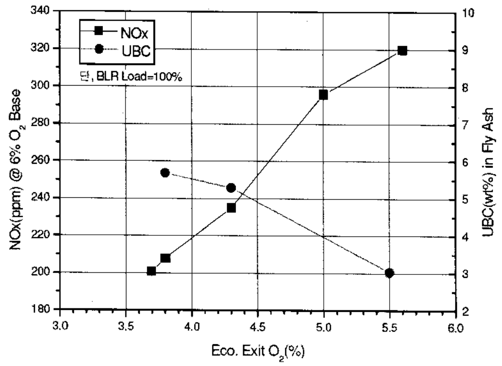


Fig. 4 Effect of excess air flow rate on NOx and UBC

Figure 5 shows the effect of OFA flow rate on NOx and UBC with the constant load and the air conditions. As the amount of OFA increases, NOx emission decreases almost linearly. But little change is shown in UBC. The decrease of NOx emission without the increase of UBC implies the effectiveness of OFA operation.

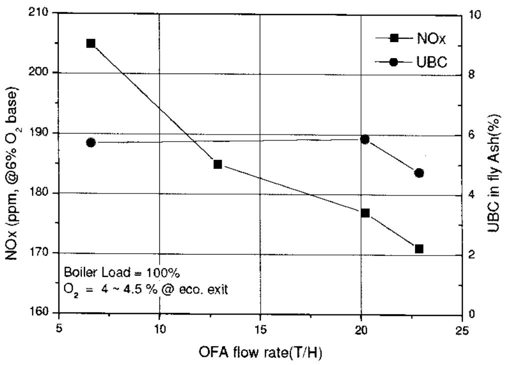


Fig.5 Effect of OFA flow rate on NOx and UBC

Figure 6 shows the effects of coal and burner adjustment on NOx emission rate. It was found out that the NOx emission was increased in the linear proportion of the fuel-N fraction in coal. The values of NOx emission were widely dispersed according to the tuning process even though the level of fuel N fraction is the same. This phenomenon accrued from changes in excess air quantity[6], unbalance of air flow rate per burner[7], difference in volatile matter content in coal[8], and changes in fineness of pulverized coal[9].

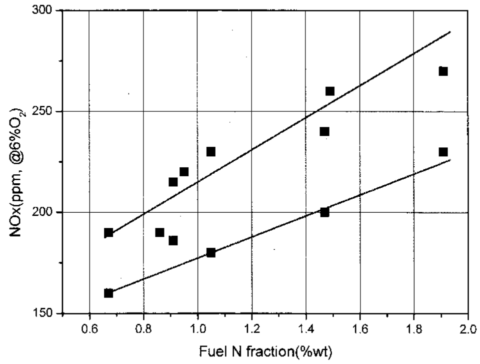


Fig. 6 Relation between NOx and Fuel-N Fraction

4. Conclusions

The Doosan low NOx pulverized coal burner was successfully applied to 130 ton/hr steam coal fired boiler and emitted 160ppm (@6% O2 basis) NOx and 3% UBC with China coal containing 0.86% fuel nitrogen. The following conclusions were obtained from the measuring results of NOx and UBC in the tuning period and commercial operation.

- In a fixed air ratio, the increased load in boiler leads to increase of gas temperature in the furnace thereby increasing NOx emission and decreasing UBC.

- The variation of NOx emission and UBC are greatly influenced by OFA flow rate as well as the air ratio supplied to the burners.

- The amount of NOx emission is proportional to the fuel-N fraction of the coal, but the values of that are widely dispersed by the operation conditions and coal properties.

Acknowledgement

This work has been supported by Korea Institute of Environmental Science and Technology. We would like to give sincere thanks to the concerned personnel of Doosan

HI & C Co., Ltd. and HUVIS Co. Ltd., who have spared no trouble in construction for application of this practice.

References

[1] R.P. van der Lans, P. Glarborg and K. D. Johansen, 1997, "Influence of Process Parameters on Nitrogen Oxide Formation inPulverized Coal Burners", Prog. Energy Combust. Sci., Vol.23, pp.349-377

[2] S.H. Kim, S.H. Song, G.M. Lee, H.J. Kim, I.H. Lee, 2001, "The Effect of Pulverized Coal Burner Design Parameters on NOx Emission", KSME Fall Conference Proceeding B, pp.102-105(Korean)

[3] A.D. Larue, H.S. Blinka, 2001, "Lower NOx/Higher Efficiency Combustion System", Pollutant Control Symposium

[4] J.M. Beer and N.A. Chigier, 1972, Combustion Aerodynamics, John Wiley & Sons,Inc

[5] A.K. Gupta, D.G. Lilley and N. Syred, 1984, Swirl Flows, Abacus Press

[6] A. Williams, M. Pourkashanian, J.M. Jones and L. Rowlands, 1997, "A Review of NOx formation and Reduction Mechanisms in Combustion Systems with Particular Reference to Coal", Journal of the Institute of Energy, Vol.70, pp.102-113

[7] R.E. Thompson, F.P. Haumesser, T.A. Davey and A. Hickinbotham, 1997, "The Role of Combustion Diagonostics in the Boiler Tuning", EPRI-DOE-EPA Combined Air Pollutant Control Symposium

[8] R.P. van der Lans, P. Glarborg and K. D. Johansen, P. Knudsen, G. Hesselmann and P. Hepburm, 1998, "Influence of Coal Quality on Combustion Performance", Fuel, Vol.77, No.12, pp.1317-1328

[9] H. Makino, M. Kimoto, S. Nishima and K. Koyata, 1989, "Development of Low-NOx and Low-Ignition Loss Combustion Technology on Pulverized Coal Combustion (Part3)", CRIEPI Report, W88031