Influence of blending method with different SR on unburned carbon and NOx emission and its application

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ABSTRACT

The influence of coal blending methods such as out-furnace (external or pre-mixed) blending and in-furnace (initially non-mixed) blending with different excess oxygen (highest, medium, and lowest stoichiometric conditions) on unburned carbon and NOx emissions of blend combustion in an entrained flow reactor (EFR) has been analyzed, using experimental and numerical approaches for binary coals used by Korean power plants. The results confirm that under the medium condition, contrasting processes such as reactive and un-reactive effects occur with SBRs in the out-furnace blending method. The in-furnace blending method results in an improvement in the efficiency of unburned carbon fractions and a further reduction in the NOx emission. Under the highest condition, the unburned carbon fraction in both the out-furnace and the in-furnace blending methods corresponds with the tendency under the medium condition with contrasting processes of lower magnitude, whereas the NOx emission in the highest condition increases slightly. Under the lowest conditions, the unburned carbon fraction in the out-furnace blending method gradually decreases as SBR decreases, without a competition effect. The reduction of NOx emission under the lowest conditions is more effective than those under other conditions for the two blending methods because of a homogeneous and heterogeneous NOx reduction mechanism.

Key Words : Blending method, Excess oxygen, Unburned carbon, NOx emission, In-furnace blending

This study was conducted to fundamentally i nvestigate the effect of excess oxygen on unb urned carbon and NOx emissions for different coal blending methods such as out-furnace ble nding and in-furnace blending using EFR.

Contrary to the previous coal feeding system of the EFR, the modified feeding system used here could inject binary coals under high temp erature conditions by using a water-cooled inje ction probe. The mixing time between binary c oals could be varied, as will be described belo w, and two feeders were installed in the inject ing section to feed different types of coal. One coal was supplied directly into the side of the injection probe and another coal was fed into a center tube installed with a cooling system.

The total gas flow rate mixed with O_2 and $N_2$was 5L/min (at 273K,1 atm) and O_2 concent ration prior to the reaction was controlled at 9%,12%, and 13.5% to represent lowest, mediu m, and highest stoichiometric conditions, respec tively. The lowest and highest stoichiometric c onditions represented less oxygen level and en hanced excess air levels than that of medium condition. At this time, the excess oxygen coef ficient (λ) for the medium stoichiometric condit ion was 1.3 to 1.5; for the lowest stoichiometri c condition, 1.0 to 1.2; and for the highest stoi chiometric condition, 1.5 to 1.7 with SBR due t o coal elements.

The furnace geometry was modeled with a two-dimensional (2D) mesh comprised of

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41,000 cells. Fig. 3 presents that gas flow and injection points of binary coals showing relative geometries and comparison of temperature between numerical modeling and experiment of the EFR used during simulation. The injection of the binary coals with carrier gas was downward and the internal gas temperature was constant. The experimental conditions used in this study are applied as boundary conditions of the numerical simulation.

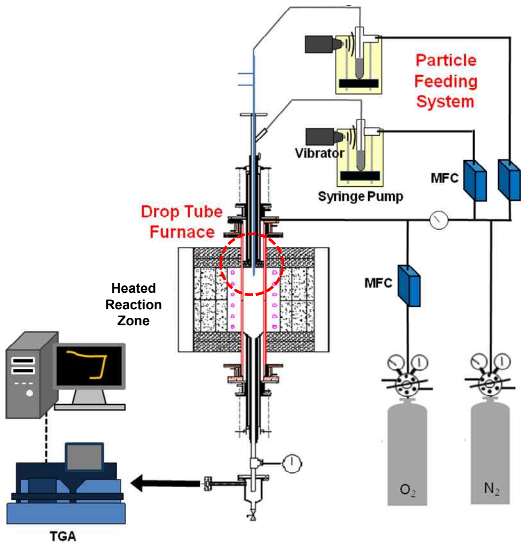

Fig. 1 Schematic diagram of the modified EFR apparatus.

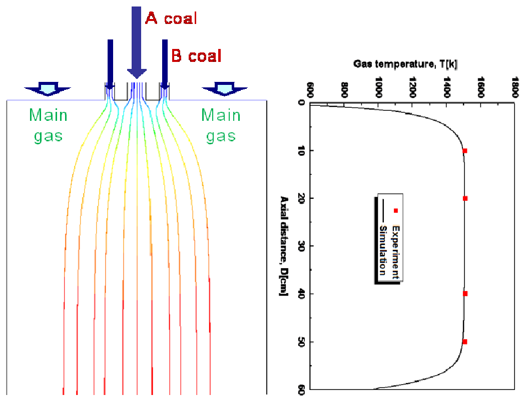

Fig. 2 Gas flow and injection points of binary coals showing relative geometries.

Under the medium conditions, which represent typical levels of excess oxygen in air, it was confirmed that in the out-furnace blending method, contrasting processes such as reactive and un-reactive effects occur with SBRs and the worst condition for burning was found at an SBR of 75%. In addition, the in-furnace blending method was suggested in order to mitigate the adverse effect of unburned carbon and to reduce NOx emissions. The in-furnace blending method resulted in an improvement in the efficiency of unburned carbon fractions and a further reduction in the NOx emission.

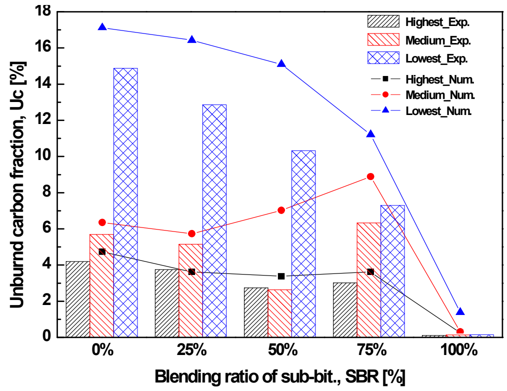

Fig. 3 Comparison of unburned carbon fractions as a function of SBR at 3 different excess oxygen conditions in out-furnace blending.

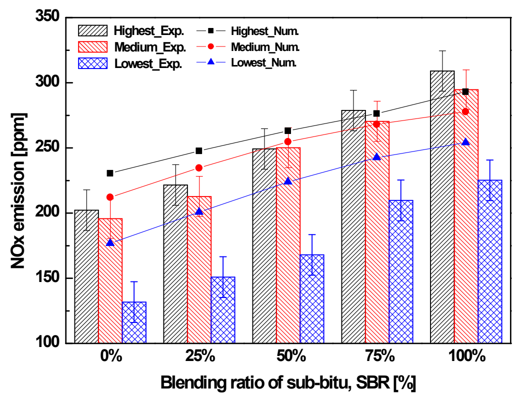

Fig. 4 Comparison of NOx emission as a function of SBR at 3 different excess oxygen conditions in out-furnace blending.

Under the highest conditions, which represents enhanced levels of excess air, the best conditions for unburned carbon fraction in the out-furnace blending method was observed at an SBR of 50%; a slight oxygen deficiency environment is formed at SBR 75%, the same as those under the medium condition. The unburned carbon fraction in the in-furnace blending method decreases and the position where keep similarly the magnitude is shorter. Meanwhile, NOx emission under the highest conditions increases slightly.

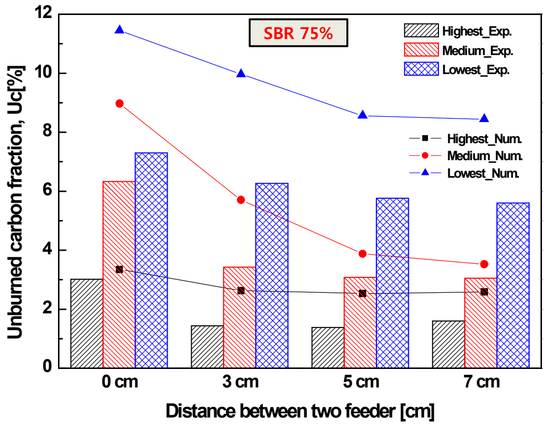

Fig. 5 Comparison of unburned carbon fractions as a function of feeder distance at 3 different excess oxygen conditions in the in-furnace blending.

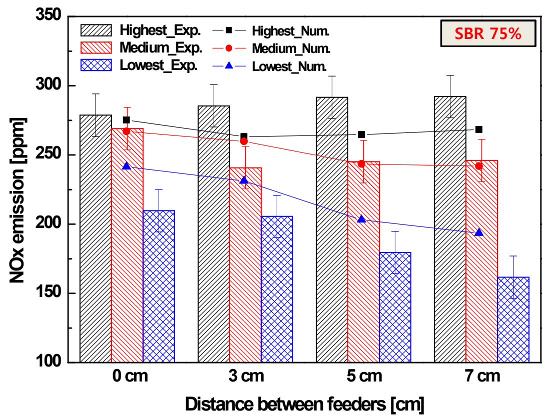

Fig. 6 Comparison of NOx emission as a function of feeder distance at 3 different excess oxygen conditions in the in-furnace blending.

Under the lowest conditions, this represents an oxygen-lean atmosphere than the medium conditions, the unburned carbon fraction in the out-furnace blending method decreases gradually from SBR 0% to SBR 75% without any competition effect. The unburned carbon fraction in in-furnace blending methods also gradually decreases and the reduction of the NOx emission is more effective than those under other conditions because of homogeneous and heterogeneous NOx reduction mechanism.

These results imply that the in-furnace blending method under the medium conditions would be an effective method to improve combustibility and NOx emission.

The numerical modeling was conducted using the commercial CFD software FLUENT code and reasonably predicted experimental results on unburned carbon and NO emission in the out-furnace and in-furnace blending methods with different excess oxygen, and suggested that to estimate the characteristics of NOx emission more precisely, the NOx emission model, which takes the heterogeneous mechanism (catalytic effect of NO reduction on the char-N oxidation) into account, should be incorporated in numerical modeling as well as homogeneous mechanism.

Acknowledgments

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