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Modelling Of Pulverized Coal Combustion with the Char Structure Effect in Melter-Gasifier

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Extended Abstract

In the ironmaking process, the melter-gasifier is responsible for the reduction of iron ore by coke, a smelting process. In melter-gasifier, pulverized coal is introduced with the oxygen through tuyeres as a heat source for iron ore reduction. The kinetic energy of oxygen stream creates a cavity, raceway, in front of each tuyere, and the coal particles are burned in the raceway under high pressure and temperature ambient. In general, high-rank coal were considered as pulverized fuels, however, low-lank coals with high volatile content have begun to attract attention to secure price competitiveness. However, the higher volatile coal, the higher possibility of fragmentation due to thermal shock and overpressure generated in particles by devolatilization in the early instances of coal combustion[1]. In some low-rank coals, agglomeration due to particle sintering also occurs. This effects of char structure change the specific surface area of char and affect the combustion characteristics[2-3].

There are several computational fluid dynamic (CFD) studies for the blast furnace, one of the ironmaking furnace, and coal/coke reactions[4-7]. However, recent studies have focused on the raceway dynamics generated by PCI, and a three-dimensional CFD modelling study considering the effect of char structure in pulverized coal combustion process does not exist yet. In terms of char fragmentation modelling, several lab-scale pulverized coal combustion CFD models have been presented through various approaches[8-10]. In addition, these effects cannot be considered in typical static combustion experiments such as thermogravimetric analysis (TGA) and therefore have different properties than combustion in a melter-gasifier.

In present work, three-dimensional CFD model considering the char structure effect was proposed. The simulation includes raceway and surrounding coke bed area of a full-scale melter-gasifier.

To confirm the fragmentation and agglomeration of high volatile coal, a lab-scale pulverized coal combustion experimental instrument Drop Tube Furnace (DTF) was used. Through DTF experiment and particle size distribution (PSD), scanning electron microscope(SEM) analysis of char particles, the change of char structure was confirmed. DTF model was set up for the simulation and the novel combustion model was completed with user-defined function (UDF). In addition, the results of the DTF simulation implemented as combustion model was validated with experimental data. Based on the DTF simulation results, a UDF-implemented melter-gasifier model was developed and the effect of char structure in coal combustion was confirmed. Also, in-furnace phenomena such as flow, temperature, and gas composition were analysed.

The results of our study can predict the combustion characteristics of coal in the raceway and coke bed more accurately by considering the effect of char structure. Because of the complex operating characteristics inside the melter-gasifier, CFD simulation indicate a better understanding of the in-furnace phenomena. Furthermore, since the change in char structure occurs frequently in melter-gasifier, it is important in terms of calculation accuracy to consider these effects.

References

[1] O. Senneca, S. Heuer, P. Bareschino, M. Urciuolo, F. Pepe, M. schiemann, R. Chirone and V. Scherer, "Fragmentation of pulverized coal in a laminar drop tube reactor: Experiments and model," *Proceedings of the Combustion Institute*, vol. 39, pp. 2849-2855, 2019

[2] O. Senneca, P. Bareschino, M. Urciuolo, R. Chirone, "Prediction of structure evolution and fragmentation phenomena during combustion of coal: Effects of heating rate," *Fuel Processing Technology*, vol. 166, pp. 228-236, 2017

[3] J.H. Kim, R.G. Kim, G.B. Kim and C.H. Jeon, "Effect of coal fragmentation on PCI combustion zone in blast furnace," *Experimental Thermal and Fluid Science*, vol. 79, pp. 266-274, 2016

[4] Y.S. Shen, B.Y. Guo, A.B. Yu, P.R. Austin and P. Zulli, "Three-dimensional modelling of in-furnace coal/coke combustion in a blast furnace," *Fuel*, vol. 90, pp. 728-738, 2011

[5] Y. Zhuo and Y.S. Shen, "Three-dimensional transient modelling of coal and coke co-combustion in the dynamic raceway of ironmaking blast furnaces," *Applied Energy*, vol. 261, 114456, 2020

[6] L. Jiang, Y. Zhao, Y. Meng, S. Tu, Z. Chen, H. Yu and X. Hou, "Numerical simulation of co-injection of pulverized coal and blast furnace gas separated by a membrane," *Ironmaking & Steelmaking*, vol. 48, no. 3, pp. 324-333, 2021

[7] S. Wang and Y.S. Shen, "CFD-DEM modelling of raceway dynamics and coke combustion in an ironmaking blast furnace," *Fuel*, vol. 302, 121167, 2021

[8] N. Syred, K. Kurniawan, T. Griffiths, T. Gralton and R. Ray, "Development of fragmentation models for solid fuel combustion and gasification as subroutines for inclusion in CFD codes," *Fuel*, vol. 86, pp. 2221-2231, 2007

[9] B. Kreutzkam, C. Wieland and H. Splietoff, "Improved numerical prediction of ash formation and deposition using a novel developed char fragmentation model," *Fuel*, vol. 98, pp. 103-110, 2012

[10] R. D. Jovanovic, D.B. Cvetinovic, P.L. Skobalj, P.L. Stefanovic, P.D. Škobalj and Z.J. Markovic, "Novel fragmentation model for pulverized coal particles, gasification in low temperature air thermal plasma", *Therm. Sci.*, vol. 20, no. 1, pp. 207-227, 2016.