

Modeling and Simulation on the Reacting Flow Field and the Performance of Coal Gasifier by Using Computational Fluid Dynamics Method

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Abstract

Computational modeling and simulation are conducted on Korean IGCC test-bed coal gasifier to optimized burner design by CFD method. The CFD modeling is made by combining Reynolds-stress averaged Navier-Stokes equation solvers, turbulence, discrete phase and gasification reaction models. The present CFD simulation method calculates gas flow path, coal particle track, temperature, CO and H₂ distributions inside gasifier with changing the secondary oxidizer injection ratio as a burner design condition, and their calculation results are compared and examined to optimize burner design.

Keywords-component; CFD, Coal gasification, Secondary injection ratio, Cold gas efficiency, Carbon conversion.

1. Introduction

IGCC(Integrated Gasification Combined Cycle) is an emerging clean coal technology with superior energy and environmental efficiencies compared with conventional coal-fired boiler system[1], so worldwide R&D efforts on IGCC have been being performed in USA, Europe, China, Japan and also in Korea. Korean IGCC project has been being carried out to construct 300MW commercial scale power plant and, along with the commercial one, new Korean-type coal gasification process are being developed through 50 ton/day test-bed coal gasification facility. In the present study, computational analyses are conducted on Korean IGCC test-bed coal gasifier to optimized burner design by CFD method. The CFD modeling is made by combining

Reynolds-stress averaged Navier-Stokes equation solvers, turbulence, discrete phase and gasification reaction models. The present CFD simulation method calculates the gas flow path, the coal particle track, the temperature, the CO and H₂ distributions inside gasifier with changing the secondary oxidizer injection ratio as a burner design parameter, and their calculation results are compared and examined to optimize burner design.

2. Modeling and Simulation Methods

2.1 Design concept and feedstock condition of coal gasifier

An entrained-bed coal gasifier for Korean IGCC test-bed application is designed with the bituminous coal of proximate analysis results(6% moisture, 51% fixed carbon, 28% volatile, 15% ash), and its feedstock conditions are 20 ton/day of coal, 15 ton/day of oxygen, 2 ton/day of steam and 3 ton/day of nitrogen. It is noted oxygen and steam are used as the oxidizer of coal while nitrogen used as coal-conveying gas. The operating conditions of gasifier are 20 atm(g) and 1400°C.

Korean test-bed gasifier is designed with entrained-bed type, aspect ratio(L/D) of 6 and co- axial coal burner, primary and secondary oxidizer nozzles as shown in Fig.1. All the burner and the nozzles are equipped on the top section of gasifier to secure partial-slagging gasifier operation.

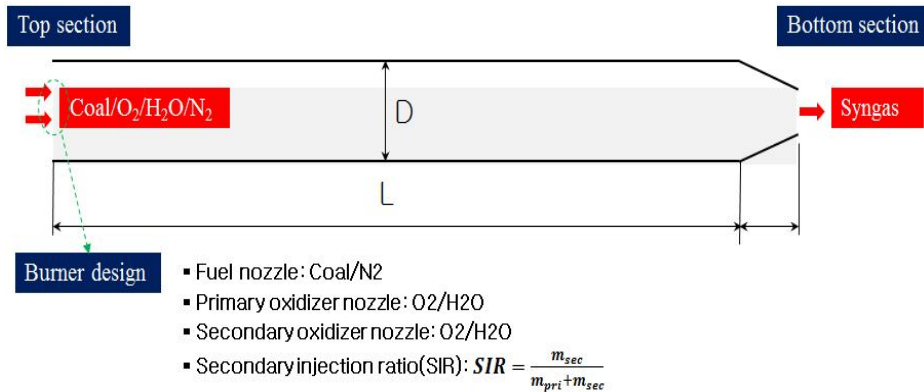


Fig. 1: Design concept of gasifier.

2.2 CFD model and analysis methods

The numerical modeling and simulation by CFD method are made to optimize oxidizer distribution ratio for maximizing gasifier efficiency. As summarized in Fig. 2, the present CFD model is based on the RANS(Reynolds-stress Averaged Navier Stokes equations) solvers coupled with realizable k-ε turbulence, discrete-phase models and chemical kinetics models for gas phase and char surface gasification reactions. Discrete phase model are based on the iterative computations for the Eulerian and the Lagrangian approaches for gas and coal-solid flows, and employs the Random walk model for considering the coal particle dispersion by turbulence[2].

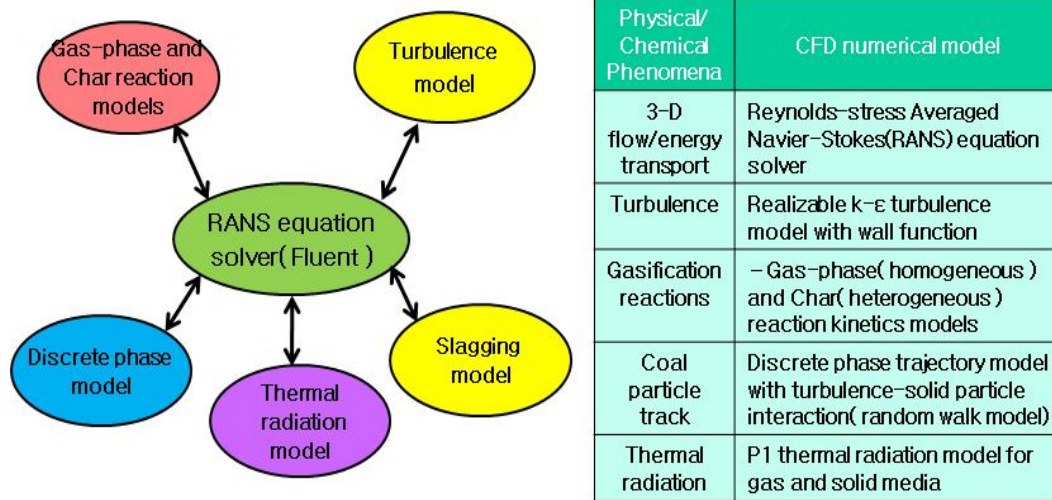
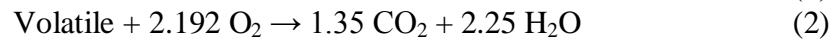
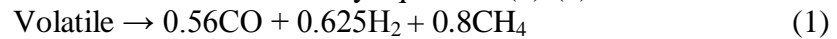


Fig. 2: CFD models and analysis methods.

In the present study, coal is assumed to be decomposed into volatile and char, and the devolatilization of coal is calculated by using two competing-rate model by Kobayashi[3]. Gas phase reactions are modeled by equations (1)-(7) as follows:



Char surface reactions are analyzed by the apparent rate/diffusion rate model for three kinds of reactions as follows:



Here all the kinetic data of equations (1)-(10) such as pre-exponential factor and activation energy are referred to Watanabe and Otaka[4].

3. Results and Discussions

The present study examines the gasification performances such as cold gas efficiency and carbon conversion and the gas composition of gasifier with changing primary nozzle size(D_p) and secondary injection ratio(SIR). Figs. 3 and 4 show the gas composition of CO and H₂ at gasifier exit. As shown in Figs. 3 and 4, when D_p is increased or decreased from reference size, CO composition is increased up to

maximum 62% and H_2 composition is reduced down to 23%. However, the compositions of CO and H_2 are remained as almost constant values of 46% and 30% at reference nozzle size($D_{p,ref}$) in spite of changing SIR.

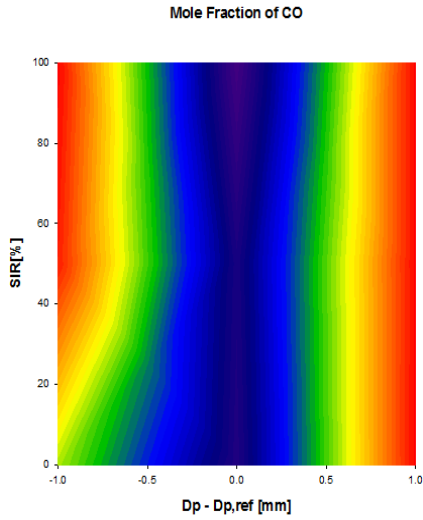


Fig. 3: CO composition of gasifier exit.

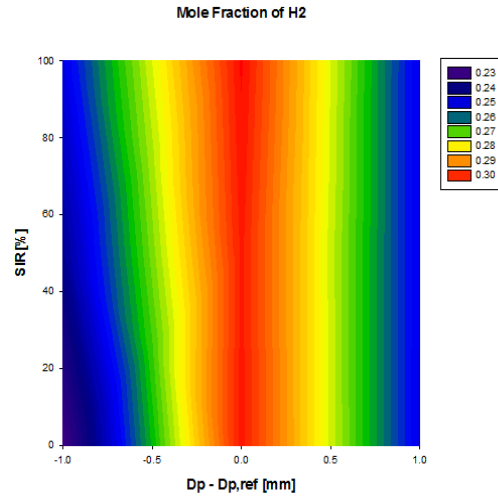


Fig. 4: H_2 composition of gasifier exit.

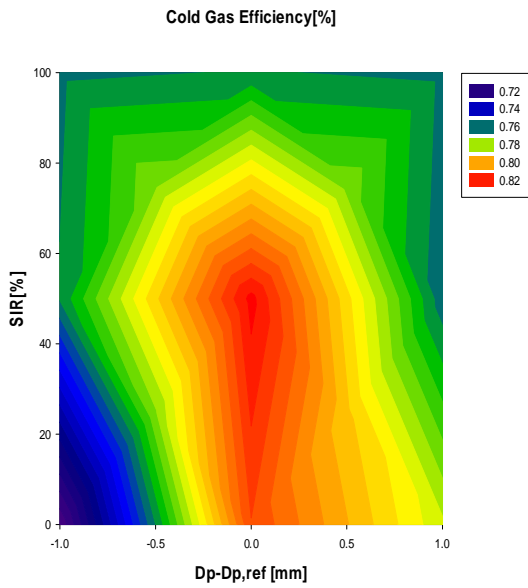


Fig. 5: Cold gas efficiency of gasifier.

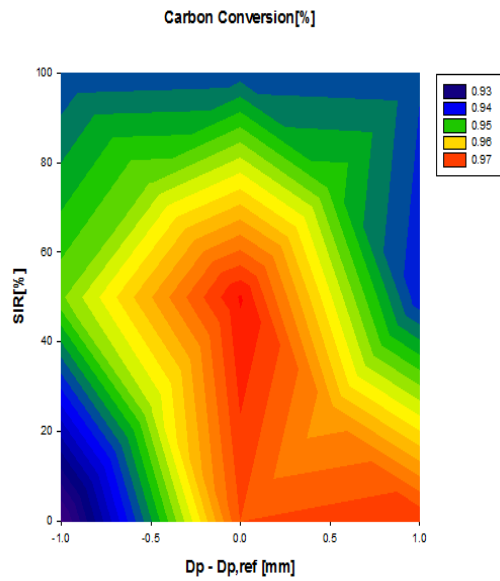


Fig. 6: Carbon conversion of gasifier.

Figs. 5 and 6 also represent the coal gas efficiency and the carbon conversion of gasifier, which are the highest, 82.2% and 97.3%, at $SIR=0.5$ and reference nozzle size.

4. Conclusion

Computational analyses by CFD code are conducted to optimize the design conditions for coal burner, oxidizer primary and secondary nozzles of Korean test-bed coal gasifier. With the design feedstock as a bituminous coal, the simulations on the reacting flow field in gasifier are made by changing primary nozzle size and secondary injection ratio(SIR). The simulation results at SIR=0.5 and reference nozzle size show the best coal conversion and cold gas efficiency of 97 % and 82%.

5. Acknowledgement

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