Prediction of gasification characteristics of the gasifier in a demonstration plant by numerical simulation

Background

The test operation of a 250 MW IGCC demonstration plant was started in 2007 by Clean Coal Power R&D Co., Ltd.. In order to complete the demonstration project successfully, it is important to support the project in the present operation phase by prediction and evaluation of the gasification characteristics of the gasifier in the demonstration plant.

Objectives

To predict the effects of the operating conditions on the gasification characteristics of the gasifier when the design coal [*1] is used by the numerical simulation based on the coal adaptability evaluation method (Fig.1) [*2*3];

Principal Results

Numerical simulations on the gasifier of the demonstration plant using the design coal were performed for the cases varying ±4% range of the base air ratio [*4] by the coal adaptability evaluation method which has been developed by CRIEPI. Results are as follows.

1. Flow pattern and particle behavior

In the range of air ratio in this study, since a swirling flow similar to that in the gasifier of the pilot plant is formed, the flow pattern is considered to be preferable. (Fig.2) However, for the case of high air ratio, the fact that the high temperature particles are entrained into the redactor region implies the possibility of ash particles deposition on the inner wall in the downstream.(Fig.3)

2. Major gasification performance

When the air ratio decreases by 4% of the base condition, the calorific value of product gas and cold gas efficiency [*5] increase by 4% and 2%, respectively. (Fig.4) However, on the other hand, it is necessary to determine air ratio in which amount of char does not exceed capacity of the char recycling system, since the char product rate indicates increase by 37%.(Fig.5)

3. Discharge characteristics of molten slag

The thickness of the slag layer on the combustor bottom increases by 13% with decrease in air ratio by 4%, while it decreases by 17% with increase in air ratio by 4%. Overflow phenomenon, which causes instability of slag discharge, is not observed in the slag tap hole region in any cases.(Fig.6)

4. Scattering of molten slag [*6]

For the case of higher air ratio condition, Weber number approaches the limit Weber number of droplet scattering on inner walls, since the gas velocity near the wall of the throat region increases. In the range of air ratio in this study, it is not possible to observe the scattering phenomenon in the throat region at any rate.(Fig.7)

Future Developments

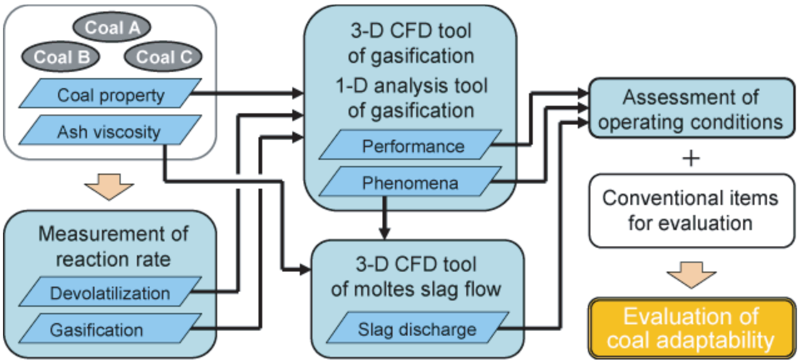
Prediction of gasification characteristics using coals proposed to diversify coal types which can be applied to the demonstration plant will be performed, and gasification characteristics based on the actual demonstration test data will be evaluated.

Main Researcher: Hiroaki Watanabe,
Research Scientist, Fuel Reforming Sector, Energy Engineering Research Laboratory

Reference

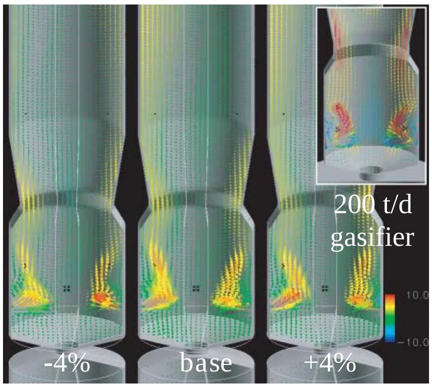
H. Watanabe and S. Hara., 2007, "Development of evaluation method of gasification characteristics and coal adaptability for commercial class coal gasifier," CRIEPI Report M06401 (in Japanese)

＊1：design coal: coal type for evaluation of plant performance
＊2：CFD tool for gasification reaction in a gasifier (CRIEPI Report W09015)
＊3：CFD tool for molten slag flow in a gasifier (CRIEPI Report W03021)
＊4：air ratio: stoichiometric value for unit weight of coal, operating paramete
＊5：cold gas efficiency: parameter for evaluation of gasification efficiency
＊6：evaluation method of scattering of molten slag (CRIEPI Report W09031)



In addition to coal fuel ratio, heating value and fusion point of ash, the accuracy of the evaluation of coal adaptability can be improved by the prediction of the phenomena in detail inside the gasifier using a numerical simulation.

Fig.1 Evaluation procedure for coal adaptability based on numerical simulation



< Swirling flow similar to that in the pilot gasifier is observed. Flow pattern is preferable.

> For higher air ratio, the fact that high temperature particles are entrained into the redactor region implies ash particles deposition on inner walls.

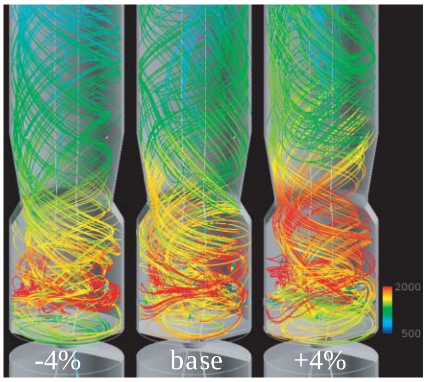


Fig.2 Velocity vectors on vertical plane (Color indicates axial velocity)

Fig.3 Particle trajectories (Color indicates particle temperature)

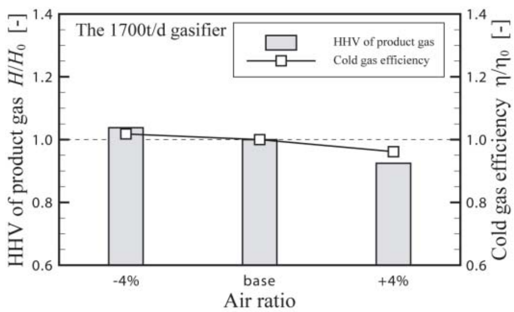


Fig.4 Effect of air ratio on HHV of product gas and cold gas efficiency

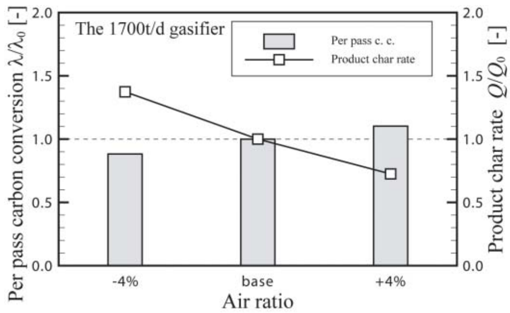
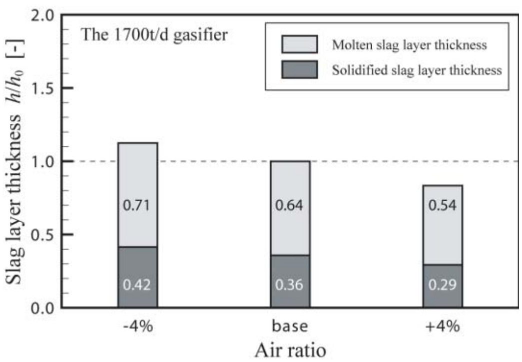


Fig.5 Effect of air ratio on per pass carbon conversion and product char rate

With decreasing air ratio, HHV of product gas and cold gas efficiency become to be improved, while product char rate increases. Thus, air ratio should be determined by limit of capacity of recycling char system.



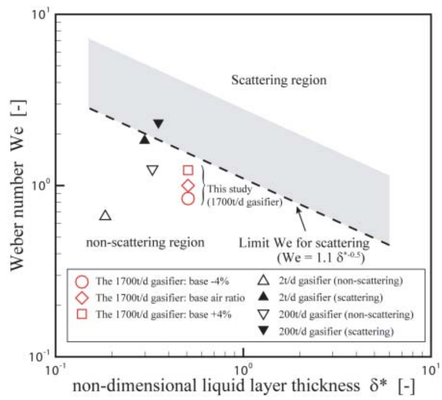


Fig.6 Effect of air ratio on slag layer thickness

Fig.7 Effect of air ratio on Weber number

In the range of air ratio in this study, overflow phenomenon and scattering of molten slag are unlikely to happen.