Evaluation of Operating Condition of Air-blown Coal Gasifier Using CFD Tool – Gasification Performance and Molten Slag Discharge under Low Air Ratio –

Background

Improvement of cold gas efficiency by low air ratio operation is important to achieve a highly efficient operation of an air-blown coal gasifier. However, there is a possibility of increase of facility cost and difficulty of stable operation because of increase in the amount of product char and difficulty of molten slag discharge due to decrease of temperature. There is an oxygen enriched air operation which can maintain the temperature and improve the per pass carbon conversion as one of the means to solve such a problem. Then, it is important to clarify the influence of oxygen concentration in low air ratio on gasification performance and molten slag discharge.

Objectives

To perform numerical simulation to clarify influence of oxygen concentration in low air ratio on gasification performance and molten slag discharge, and to establish evaluation method of operating conditions of air-blown coal gasifier.

Principal Results

Numerical experiment that changed the oxygen concentration of the gasifying agent in the extremely low air ratio [*1], which was difficult to confirm experimentally, was executed on the two stages air-blown coal gasifier (tested conditions : Fig. 1 and Table 1), and the following findings were obtained.

(1) Effectiveness of an increase of the oxygen concentration of the gasifying agent to the per pass carbon conversion and the control of the amount of product char was quantitatively clarified in extremely low air ratio conditions (Fig. 2). An important index of the coal reactivity was obtained for the evaluation of the gasifier capacity.

(2) Slag temperature was predicted from the calculation results of the heat received by the slag flowing on the combustor inner wall and the slag volume and residence time that were estimated by the gas-liquid two phase flow calculation [*2]. In addition, the influence of the air ratio and the oxygen concentration on the slag viscosity that is the most important factor of the slag discharge were clarified by application of the semi-empirical slag viscosity model [*3] (broken lines in Fig. 3).

(3) An index for the evaluation of the operating condition of the gasifier was obtained by the analysis of the tendency of the slag viscosity and the cold gas efficiency changing the air ratio and the oxygen concentration. The index can be used for the evaluation of the operating conditions that can achieve high gasification efficiency and stable slag discharge [*4] (Fig. 3).

Future Developments

Verification and improvement of the evaluation method presented in this paper will be done by the experimental study of the molten slag discharge characteristics using FRONTIA, newly set up coal gasifier in CRIEPI.

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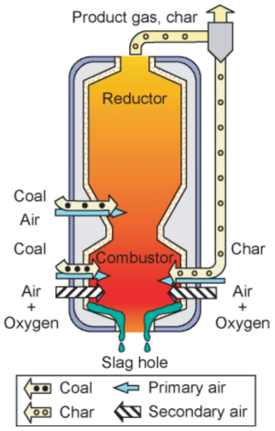
Reference

Hiroaki Watanabe, 2004, “Prediction of Air-blown Entrained Flow Coal Gasifier Performance using Numerical Simulation Technique”, CRIEPI Report, W03027

*1 : According to the experience of the test of 2 t/d coal gasifier, it is difficult to discharge slag of Coal M less than air ratio 0.47.
*2 : Otaka et al., CRIEPI Report, W03021, (2004).
*3 : Browning, G. J. et. al., "An Empirical Method for the Prediction of Coal Ash Slag Viscosity," Energy & Fuels, 17,pp.731-737(2003).
*4 : It was assumed that the threshold viscosity that stable operation become to be difficult is the critical viscosity at which slagflow start to behave as a non-Newtonian fluid.



(1) Coal : Australian M
Feeding rate : 100[kg/h]
(R/C = 60/40 [kg/kg])
(2) Oxygen enriched air is injected from combustor and char burner.
(3) Burner velocity : Const.
(4) Performance is evaluated including char recycling system.

Fig.1 Calculated conditions

Table1 Calculated conditions

Air ratio	–	0.39, 0.41, 0.43, 0.47
Oxygen concentration	vol%	21, 30, 40

It is possible to reduce air ratio to 0.425, keeping the amount of char equal to at air ratio 0.47, with 40% oxygen enriched operation.

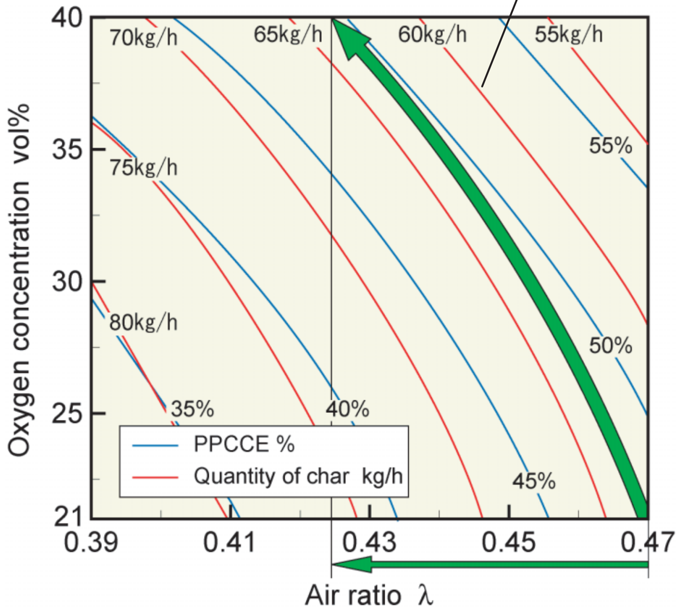
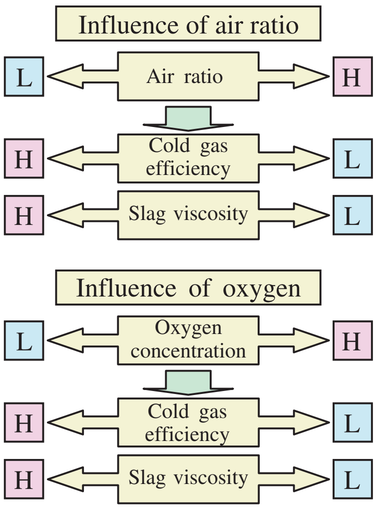
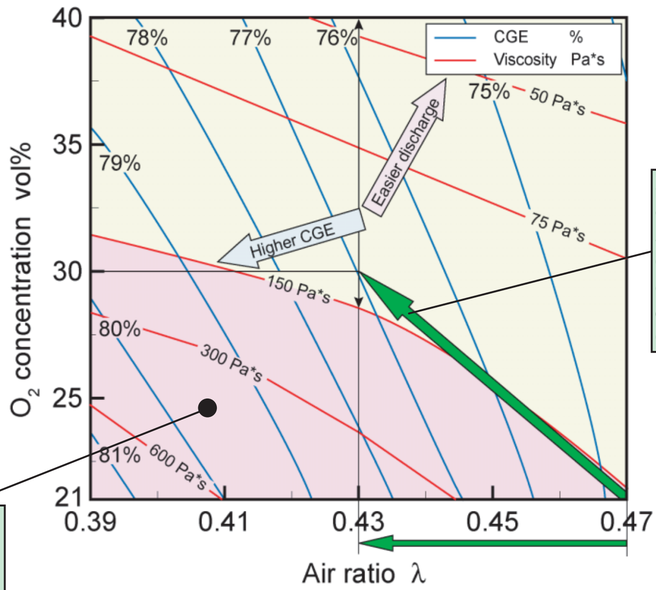


Fig.2 Trend of per pass carbon conversion and the amount of product char, changing air ratio and oxygenconcentration

The effects of air ratio and oxygen concentration on per pass carbon conversion and the amount of product char were clarified. An important index of coal reactivity was obtained for evaluation of gasifier capacity.





30% oxygen concentration operationcan achieve stable slag dischargein air ratio 0.43 and improve 2% ofcold gas efficiency compared within air ratio 0.47

Slag flow shows non-Newtonian fluid behavior and difficulty of slag discharge is expected when slag viscosity becomes 150 Pa*s or more (red region in Fig. 3). Operating shouldevade this region.

Fig.3 Trend of cold gas efficiency and slag viscosity changing air ratio and oxygen concentration

The index that can be used for the evaluation of the operating conditions to achieve high gasification efficiency and stable slag discharge was obtained.