Project Research — **Development of a Supply/Demand Infrastructure for Next-generation Electric Power**

Thermal Power Generation Systems with CO_2 Capture

Background and Objective

The reduction of CO_2 emissions in coal thermal power generation for global warming control is an important matter for electric utilities. Therefore, high-efficiency technology and biomass utilization are promoted for some power generation systems. Attention is paid to CO_2 Capture and Storage (CCS) as one of the effective countermeasure against global warming in recent years. In Europe and the United States, many CCS projects have been announced. However, the current CCS technology exhibits many problems, such as a significant drop in power generation efficiency and an increase in cost.

To offer a futuristic option that solves these problems, CRIEPI has proposed a highly efficient IGCC system with CO_2 capture (Fig. 1). In this project, we will develop O_2-CO_2 blown gasification technology and semiclosed GT technology.

Main results

1 Effect of Enriched CO_2 on Gasification Reaction Promotion in a Bench-scale Coal Gasifier*

In an O_2-CO_2 blown gasifier, a gasification reaction promotion by enriched CO_2 can be expected. On the other hand, a drop in the temperature in the gasifier is a problem because CO_2 has a higher molar-specific heat. CO_2 was used for a carrier gas component in our 3 t/day bench-scale coal gasifier, and the combustor temperature was held constant, adjusting the oxygen concentration in the gasifying agent, to examine the gasification characteristics (Fig. 2). As a result, the carbon conversion efficiency was improved at a high CO_2 concentration when the temperature in the gasifier was properly maintained by adjusting the oxygen concentration in the gasification agent (M11019).

2 Numerical Modeling of O_2-CO_2 Blown Coal Gasification

An O_2-CO_2 blown coal gasification reaction model was developed and validated to be utilized in the process of the design and optimization of a practical-scale O_2-CO_2 blown gasifier. Modified char gasification and water-gas-shift reaction models were developed and implemented with CRIEPI's three-dimensional CFD code, which had already been validated through air-blown gasification experiments. In comparison with the experimental results* of the 3 t/day gasifier (Fig. 3), it was confirmed that the model presented here could capture the general feature of gasification characteristics (Fig. 4) (M11017).

3 Combustion Promotion in Oxy-fuel Semiclosed Cycle Gas Turbines

The oxy-fuel IGCC (Fig. 1) employs a semiclosed-cycle gas turbine system, in which CO-rich coal gases are burnt with oxygen under stoichiometric conditions and diluted with recirculated gas turbine exhaust to adjust the combustor exhaust temperature. Since the higher combustion efficiency without supplying excess oxygen was required for the gas turbine in order to realize the high thermal efficiency of the IGCC system, the combustion promotion was studied using numerical analyses based on reaction kinetics. As a result, it was found that, the combustion efficiency was improved with increase of the fuel oxidation rates when the dilution gas of recirculating exhaust was divided into two parts, one was supplied into a burner at a suitable gas flow rate and the other was supplied into a combustor downstream as a secondary dilution (Fig. 5) (M11004).

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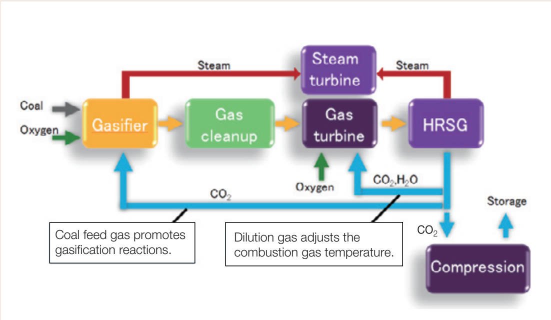

Fig. 1: Concept of a highly efficient oxy-fuel IGCC with CO_2 capture

This novel system consists of an O_2-CO_2 blown gasifier and a semiclosed GT with exhaust CO_2 circulations. It is expected to have higher thermal efficiency (more over 40%: HHV Net) and a simpler configuration, compared with the existing IGCC with CO_2 capture.

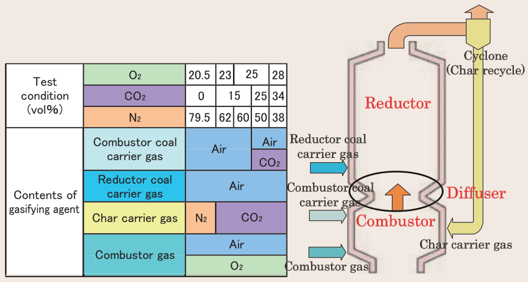

Fig. 2: Gasification testing conditions and the CO_2 feeding method

CO_2 was used for coal and/or char carrier gas in a combustor, and the O_2 supplied to the combustor was adjusted, maintaining the air ratio so that the combustor temperature became constant.

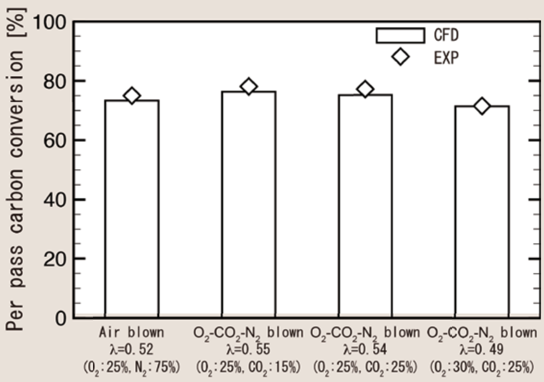

Fig. 3: Comparison of model results with experiments in the 3 t/day gasifier

The presented model could accurately estimate the gasification characteristics.

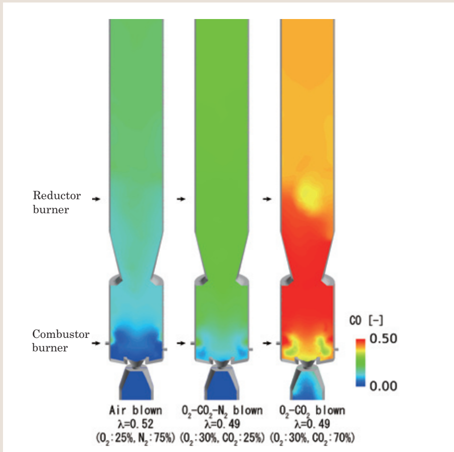

Fig. 4: Distributions of CO concentration

CO concentration in the O_2-CO_2 blown condition drastically increased at high CO_2 concentration in the gasifying agent.

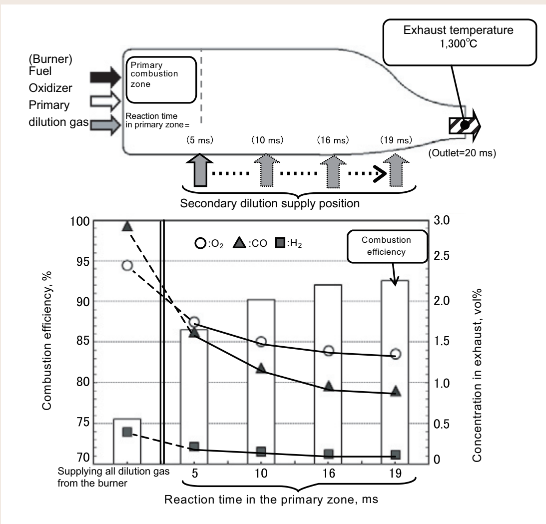

Fig. 5: Combustion promotion by dilution gas streamwise splitting

The combustion efficiency could be improved both by adjusting the primary dilution gas/fuel molar ratio to approximately 3 and by supplying the secondary dilution downstream to maintain the combustibility in the primary combustion zone.