Proposal of Advanced Integrated Coal Gasification Combined Cycle Power Generation System with CO_2 Capture

Background

CO_2 emissions control from coal fired power plants is an important issue for global warming prevention. Electric power industries are advancing various measures such as the improvement of power generation efficiency and the introduction of carbon neutral fuels such as biomass fuels to this problem. On the other hand, discussion for the application of CO_2 capture and storage (CCS) to coal fired power plants has been active internationally. However, if power plants with the current CO_2 capture technology are introduced, it will be impossible to avoid great decreases of the power generation efficiency and rises in power generating cost. For this reason, the development of new highly efficient power generating systems is desired.

Objectives

To improve the power generation efficiency and reduce the generation cost, this study aims to propose a highly efficient integrated coal gasification combined cycle power generation system with CO_2 capture, and to clarify the advantage of our proposed IGCC system through numerical analysis.

Principal Results

1. Features of proposed IGCC system with CO_2 capture (Fig. 1)

The system has a new O_2-CO_2 blown coal gasifier where captured CO_2 is effectively used. The synthesis gas is burned with the mixed gas of O_2 and CO_2-rich recycled exhaust gas in the oxy-fuel gas turbine (closed gas turbine) system. Non-recycled exhaust gas is directly compressed and CO_2 is liquefied. In this system, the gasification performance and power generation efficiency improve greatly. Furthermore, CO_2 separation process (CO_2 absorption process, etc.) is not needed.

2. Expected effects

(1) It was estimated that O_2-CO_2 blown coal gasifier improves the carbon conversion and cold gas efficiency as compared to the current O_2 blown (O_2-N_2 blown) coal gasifire and air blown coal gasifire because CO_2 enhances the gasification reaction (Table 1). These effects allow us to realize a compact gasifier and a simple char recycle system *1.

(2) The gas turbine is compacted because the inlet gas of the gas turbine is CO_2-rich and the specific gravity of CO_2 is higher than that of air. Furthermore, the CO_2-rich gas which has a low specific heat ratio, and the addition of a regenerative heat exchanger improve the power generation efficiency in the gas turbine.

(3) CO_2 separation process (CO_2 absorption process etc.) is not needed because the exhaust gas of the gas turbine is directly compressed and CO_2 can be liquefied. Furthermore, the proposed system is expected to have the efficiency of 42% (HHV) in a system with a 1300 ℃-class gas turbine and 45% in a system with a1500 ℃-class gas turbine because the addition of a regenerative heat exchanger improves the power generation efficiency (Table 2). If the molten carbonate fuel cell instead of the gas turbine is applied to this system, efficiency of near 60 % is obtained.

3. Development items

The following development items are enumerated to put this system into practical use.

- Optimization of the total system
- Realization of the compact gasifier and simple gasification system (char recycle system etc.) by making the best use of great improvement of the gasification performance
- Measures for carbon deposition in the gas cooling process and the gas cleaning process
- Optimization of the design and control method in the oxy-fuel gas turbine (closed gas turbine) system

Future Developments

It is scheduled to conduct the feasibility study (F.S.) of this system to clarify the power generating cost, and confirm the gasification performance using 3ton/day coal gasifier.

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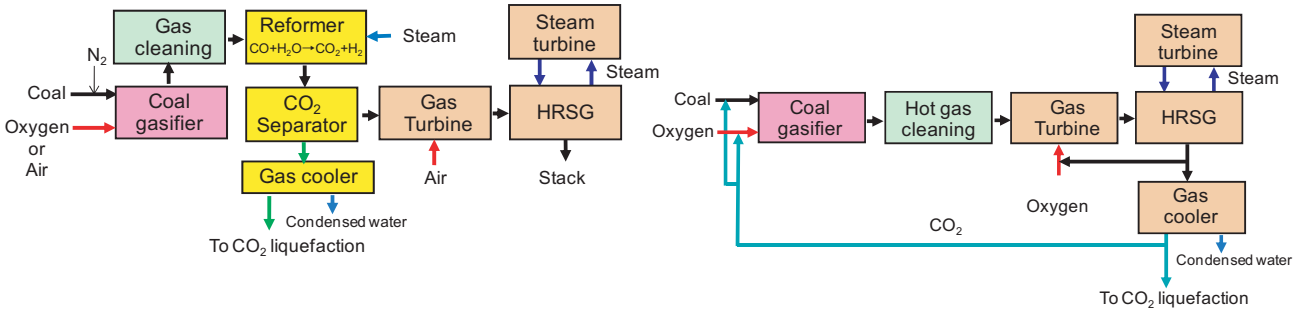
Reference

H. Shirai, et.al., 2007, "Proposal of a highly efficient system with CO_2 capture and the task on integrated coal gasification combined cycle power generation", CRIEPI Report M07003 (in Japanese)

*1 : the system where collected particles (char) containing unburnt carbon from raw coal gas are recycled to the gasifire



1) Current IGCC system with CO_2 capture　　2) Proposed advance IGCC system with CO_2 capture

Fig.1 Comparison between IGCC systems with CO_2 capture

In the current system, the carbon monoxide (CO) in the synthesis gas is reacted with steam in a catalytic reactor, called a shift converter, to yield CO_2 and more hydrogen. CO_2 is then separated by a physical or chemical absorption process. On the other hand, in the advanced system, the oxy-fuel gas turbine (closed gas turbine) system is applied, and CO_2 separation process is not needed because the synthesis gas is burned with the mixed gas of O_2 and the recycled exhaust gas instead of air to obtain CO_2-rich exhaust gas whose components are CO_2 and steam.

Table 1 Comparison of the gasification performance in three gasifire types

Gasifier type		O_2-CO_2	O_2-N_2	Air
Carbon conversion	%	100	69.9	69.5
Char				
Generated Char	t/h	13.9	51.8	58.1
Carbon content.	wt%	0	72.9	66.3
Ash content	wt%	100	27.1	23.7
Synthesis gas				
Flow rate	t/h	274.6	274.6	536.3
Calorific value	MJ/m^{3}N	11.1	10.3	5.7
CH_4	vol%	0	0	0
H_2	vol%	21.3	24.4	12.9
CO	vol%	66.5	56.9	31.8
CO_2	vol%	5.4	0	2.0
H_2O	vol%	5.3	0	2.2
N_2	vol%	1.5	18.7	51.1
Cold gas efficiency	%	80.8	78.8	76.5

It is estimated that the carbon conversion was 100% for the O_2-CO_2 blown gasifier. It means that coal is gasified perfectly. The cold gas efficiency, which is the ratio of the energy of the synthesis gas to the energy of supplied coal, is 80% which is the highest out of the three gasifier types. Therefore, the O_2-CO_2 blown gasification system presents the possibility of greatly contributing to the improvement of the gasification performance as compared to conventional gasification systems.

Table 2 Comparison of the efficiency between the O_2-N_2 blown IGCC system and the O_2-CO_2 blown IGCC system

Gasifier type		O_2 -N_2*2		O_2-CO_2	
Gas turbine type		1300 °C	1300 °C	1300 °C	1500 °C
CO_2 recovery ratio	%	0	90	Over 99	Over 99
Gross efficiency (HHV/LHV)	%	47.7/49.8	42.7/44.7	56.9/59.6	60.0/62.8
Net efficiency (HHV/LHV)	%	42.5/44.5	34.9/36.5	42.1/44.1	45.1/47.2

*2 NEDO report No. 04002145-0, 2005.3 (in Japanese)

In the O_2-CO_2 blown IGCC system (1300℃ class gas turbine), the efficiency of 42.0% at capturing CO_2 by 99% or more can be obtained and the improvement of power generation efficiency is expected. On the other hand, the efficiency in the O_2-N_2 blown IGCC system (1300℃ class gas turbine) decreases up to 34.9% when 90% of CO_2 is captured.