Thermal Efficiency of Integrated Coal Gasification Power Generation Systems with CO_2 Capture

Background

Coal burning power stations make a major contribution to the stable supply of electric power, thus, the improvement of thermal efficiency of power stations is one of the key technologies for minimizing emissions of CO_2. CO_2 capture, also, is an effective way to decrease CO_2 emissions in future coal burning power stations; a high efficiency power generation with CO_2 capture is required for the beneficial utilization of the energy sources and dilution of the CO_2 emissions. Since CRIEPI has been developing CO_2 capture methods from an integrated coal gasification power system, and simple CO_2 capture methods by the effective utilization of oxygen, the net efficiency of the power system (coal to pile bar efficiency) should be estimated including the power consumption of CO_2 capture.

Objectives

To estimate the efficiency of integrated coal gasification gas turbine combined cycle (IGCC) and integrated coal gasification fuel cell (IGFC) system with CO_2 capture, and to clarify the system configuration for easy CO_2 capture with high efficiency power generation.

Principal Results

1. Conventional design of IGCC power system with CO_2 capture. (O_2-enriched air-blown coal gasification system with gas turbine combusted by air)

Oxygen enriched air-blown coal gasifier furnace is supposed as a gasification part, and the gasified fuel gas is changed to CO_2-rich gas by water-gas shift reactor; the CO_2 included in the fuel gas is captured from the CO_2-enriched fuel gas. The gross thermal efficiency of the system is calculated to be 42% higher heating value (HHV) with the 50% capture of all CO_2 emissions of the system (Fig.1, Table 1).

2. High efficiency power system with CO_2 capture.

(1) High efficiency coal gasification system combined with closed gas turbine cycle with CO_2 capture.

Oxygen blown coal gasification system is combined with the CO_2 re-circulated closed gas turbine cycle. Other oxygen is supplied as a combustion gas of the gas turbine. The system offers a gross thermal efficiency of 57% HHV that corresponds to a net thermal efficiency of 45% HHV with 100% CO_2 capture (Fig.2, Table 1).

(2) High efficiency coal gasification system powered by fuel cell cycle with CO_2 capture.

The efficiency of the integrated coal gasification system having the molten carbonate fuel cell, the gas turbine and the steam turbine (IG/MCFC) is calculated. The water-gas shift converter is employed in the heat-up procedure of the coal gas; this method is responsible for the easy control of the fuel cell stack. The cathode gas of the MCFC is composed of CO_2 and O_2 with a composition of 66.7/33.3. A liquid CO_2 capture with a pressure of 10MPa is supposed. Using the 2.2 MPa pressurised system, the net efficiency including the consumption of CO_2 liquefaction is evaluated to be 58% HHV. Another simple CO_2 closed system configuration with no gas turbine is proposed; net efficiencies of the 2.2MPa and 0.15MPa system including the consumption of CO_2 liquefaction were determined to be 56% and 48% HHV, respectively. From the calculation results, a high efficiency with LCO2 capture is made possible by applying oxygen utilization to the IG/MCFC and GT systems. (Fig.3, Table 1)

Summarizing the discussion in this research, it is clarified that the integrated coal gasification power system realises the high efficiency power generation with CO_2 capture by the effective utilization of oxygen.

Future Developments

The effective utilization of CO_2 for a coal gasification system is analysed and the applicability, reliability and other difficulties of the CO_2 closed gas turbines and fuel cells will be discussed.

Main Researchers: Fumihiko Yoshiba, Ph. D., Research Engineer, Energy Conversion Engineering Sector, Energy Engineering Research Laboratory

Eiichi Kouda, Senior Research Scientist, Plant Engineering Sector, Energy Engineering Research Laboratory

Reference

F.Yoshiba, 2006, "High Efficiency IG/FC system with CO_2 capture", CRIEPI Report M06011 (in Japanese)

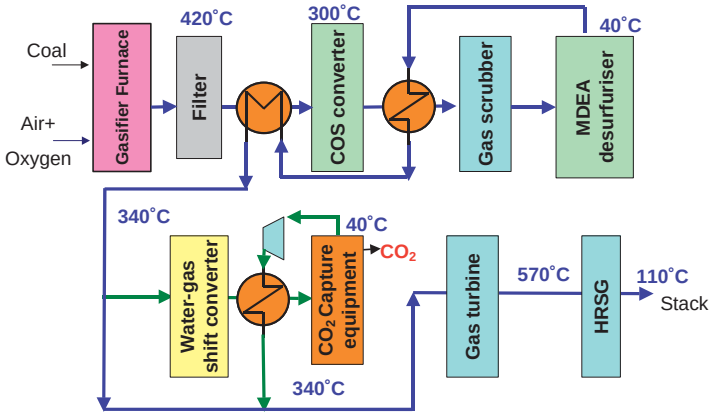

Fig.1 Conventional IGCC system with CO_2 capture.

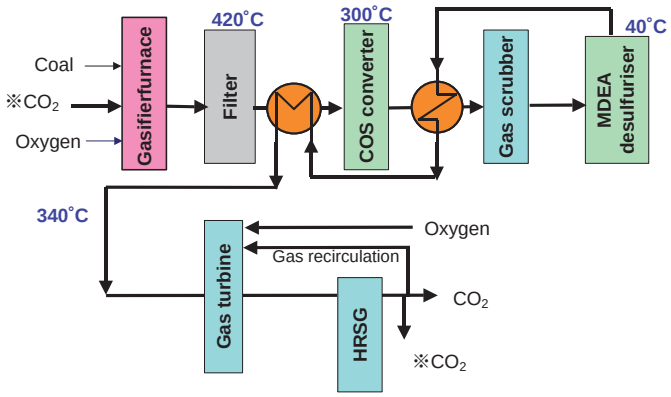

Fig.2 Advanced IGCC system with CO_2 capture.

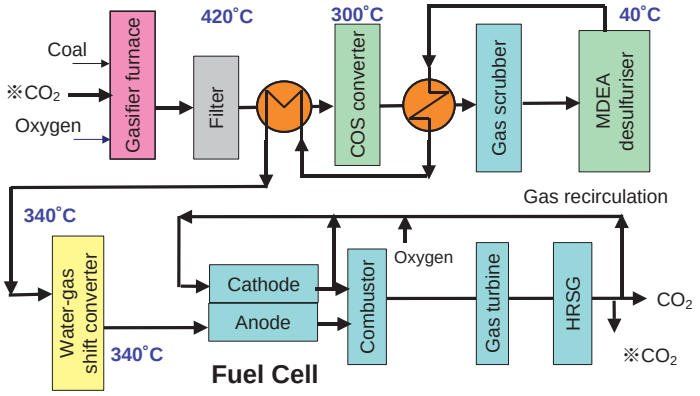

Fig.3 Advanced IGFC system with CO_2 capture.

Table 1 Efficiency of coal gasification system combined with CO_2 capture

Case	CO_2 capture efficiency (%)	Grosse fficiency (%)	NET efficiency (%)	Plant consumption (%)	CO_2 release (g/kWh)
Conventional IGCC with CO_2 capture	0	47.7	41.6	12.8	765.3
	50	42.3	34.5	18.6	413.6
Advanced IGCC with CO_2 capture	100	56.6	45.0	22.7	-
Advanced IGFC without CO_2 capture	100	70.4	60.1	15.0	-
Advanced IGFC with CO_2 capture (10MPa,LCO_2 capture)	100	67.1	56.7	15.5	-