Progress of Advanced Coal Power Plant Technology

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Increasing thermal efficiency of coal-fired power plants can greatly contribute to the conservation of the global environment and the energy security of our country. Ultra-supercritical pulverized coal-fired power plants have been already used commercially, and their thermal efficiency has attained 41%. The PFBC (Pressurized Fluidized Bed Combustion) has recently reached commercial stage. The IGCC (Integrated coal Gasification Combined Cycle) is now being developed in a demonstration plant and IGCC will accomplish a thermal efficiency of 48% with a 1 500°C class gas turbine. Also the A-PFBC and the SOFC (Solid Oxide Fuel Cell) are under development as future advanced coal technologies.

1. Introduction

To deal with an increase in consumption of coal, an energy source superior in supply stability, Mitsubishi Heavy Industries, Ltd. (MHI) has promoted development of technologies to improve the thermal efficiency of coal-fired power plants and decrease environmental pollutants such as NOx, SOx, dust, etc. In addition, MHI has made efforts to harmonize power supply and environmental conservation.

To attain the reduction targets discussed on greenhouse gases such as CO_2, by COP3 (the Third Conference of Parties to the United Nations Framework Convention on Climate Change) held in December 1997, some are suggesting a revolution in the energy supply structure through the introduction of nuclear energy, new energy, and natural gas over the long term. However, it is strongly expected that the new coal-fired power plant, a type which discharges reliably less CO_2 emission and is superior in environmental suitability, will be put urgently into practice from viewpoints of energy security and economy in the short term.

Recoverable reserves of coal amount to more than three times those of natural gas, and the combined use of coal-fired power plants with nuclear power plants can contribute to a stable power supply and energy security in Japan by optimizing efficiency using the latest advanced power plant technologies.

In the following, we introduce the development status of the latest advanced coal power plant technologies.

2. Present status of advanced coal power plant technology

2.1 USC (Ultra-Super Critical pressure steam power plant technology)

In today's power plants combining pulverized-coal-fired power plants, the mainstream of coal-fired power plants and steam turbines, thermal efficiency (hereinafter referred to as "higher heating value": HHV-based net power plant efficiency) reaches 41%, as shown in **Table 1**, by using the steam condition of ultra super-critical pressure (USC: Ultra Super Critical).

Higher efficiency in the steam condition at higher temperatures and higher pressures is limited by the properties of the high-temperature and high-strength materials used. To further upgrade economical thermal efficiency, the following technologies are being developed to optimize the performance of combined-cycle power system by combining steam turbine generation system and other power generation system.

2.2 PFBC (Pressurized Fluidized Bed Combustion) technology

In the case of combination with the gas turbine, the clean-up process in coal combustion gas is required due to the inclusion of sulfur, nitrogen, and ash contents in coal. At present, PFBC which integrates power generation by gas turbines into existing power generation by steam turbines aiming at higher efficiency of coal-fired power plants, has reached the commercial stage.

PFBC is characterized by improved thermal efficiency by changing coal-fire power plant to combined-cycle power systems and by dry clean-up via in-furnace desulfurization using limestone. The Hokkaido Electric Power Co., Inc., Tomato-Atsuma Power Plant Unit 3 is a PFBC plant with 85 MW power output constructed by MHI. The plant passed the public office test on March 9, 1998, and is smoothly running as a PFBC commercial plant equipped with the world's first high-temperature and high-performance ceramic filter[1].

Coal pressurized-plant technology, gas turbine power plant system technology, and desulfurizing and dedusting technology under high temperatures and high pressures have been demonstrated by development of PFBC. This demonstration is very significant, and the developmental base for the Integrated Coal Gasification Combined Cycle has been built up.

3. Next-generation advanced coal power plant technology—IGCC (Integrated Coal Gasification Combined Cycle)—

A 2 000 t/d-class demonstration plant for IGCC is being developed overseas.

In Japan, a demonstration plant is expected to be constructed from F. Y. 2001, and demonstration operation is scheduled to take place in F. Y. 2004.

In the IGCC now being developed by MHI, high gasification efficiency and effective gas cooling are realized at the same time by employing an air-blown pressurized two-stage entrained flow system as a coal gasifier. **Fig. 1** shows flow schemes of various coal power plants. To investigate the air-blown pressurized two-stage entrained flow system, the 200 t/d pilot plant was operated and researched at Joban Joint Power Co., Ltd. Nakoso Power Station from 1991 to 1996, and the results are being used to further scale-up to the demonstration plant. Fundamental and element experiments such as a high-

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Table 1 Status and thermal efficiency of various coal power plants

Power plant system	Study specification	Net power plant efficiency (HHV base)	Development stage
Conventional coal-fired power plant	246 kgf/cm²G, 538/538℃	38.5%	Commercial plant
Coal-fired USC power plant	246 kgf/cm²G, 600/600℃	41%	Commercial plant
PFBC	830℃ class G/T 169 kgf/cm²G, 593/593℃	41%	Commercial plant
IGCC (demonstration)	1 300℃ class G/T Wet desulfurization	42%	Demonstration stage
IGCC (commercial plant)	1 500℃ class G/T Dry desulfurization	48%	Planning stage
A-PFBC	1 300℃ class G/T In-furnace desulfurization	46%	PDU stage
SOFC	Pressurized G/T combined cycle	55%	SOFC elements are being developed.

pressure gasification reaction experiments, a pressure burner experiments, and experiments on highly condensed coal transportation are being conducted, and three-dimensional simulation program contained reactions, heat transfer, and flow dynamics are being developed[2].

Desulfurization systems in coal gasification consist of wet desulfurization at a low temperature and dry desulfurization at a high temperature of 450°C or above. Yet higher values are expected in dry desulfurization in plant efficiency. Actual results on wet desulfurization have been attained in chemical plants and can now be applied without alteration for integrated coal gasification combined cycle. However development of dry desulfurization is expected from the viewpoint of improvement of plant efficiency in the future. When the dry desulfurization system is combined with a 1 500°C class gas turbine in IGCC, a net power plant efficiency of 48 % can be realized.

4. Development of future coal power plant technology

4.1 A-PFBC (Advanced Pressurized Fluidized Bed Combustion)

A-PFBC (Advanced PFBC) is a gas turbine combined cycle using Yubari 40 t/d fluidized bed coal gasification technology in the Sunshine Project of the Ministry of International Trade and Industry and commercialized PFBC technology for higher efficiency of PFBC.

At present it is under fundamental research, and Electric Power Development Co. is expected to start an experiment using a 15t/d-class PDU (Process Development Unit) as a national project from 2001. In advance of this experiment, MHI has been engaged in the development of new technology to fix sulfur as gypsum by removing the sulfur in a high-temperature reducing atmosphere of 950°C using limestone for desulfurization in the coal gasification process. For the first time worldwide, MHI has verified the desulfurization principle.

4.2 SOFC (Solid Oxide Fuel Cell) combined cycle power system

SOFC is a power plant system utilizing the characteristic of YSZ (yttria-stabilized zirconia), which is a solid electrotype, passing oxygen ion at high temperature. In this process, the chemical energy of fuel can be converted directly to electric energy. When coal is gasified as fuel by the combined cycle of

ST: Steam turbine, GT: Gas turbine, C: Air compressor, HRSG: Heat Recovery Steam Generator

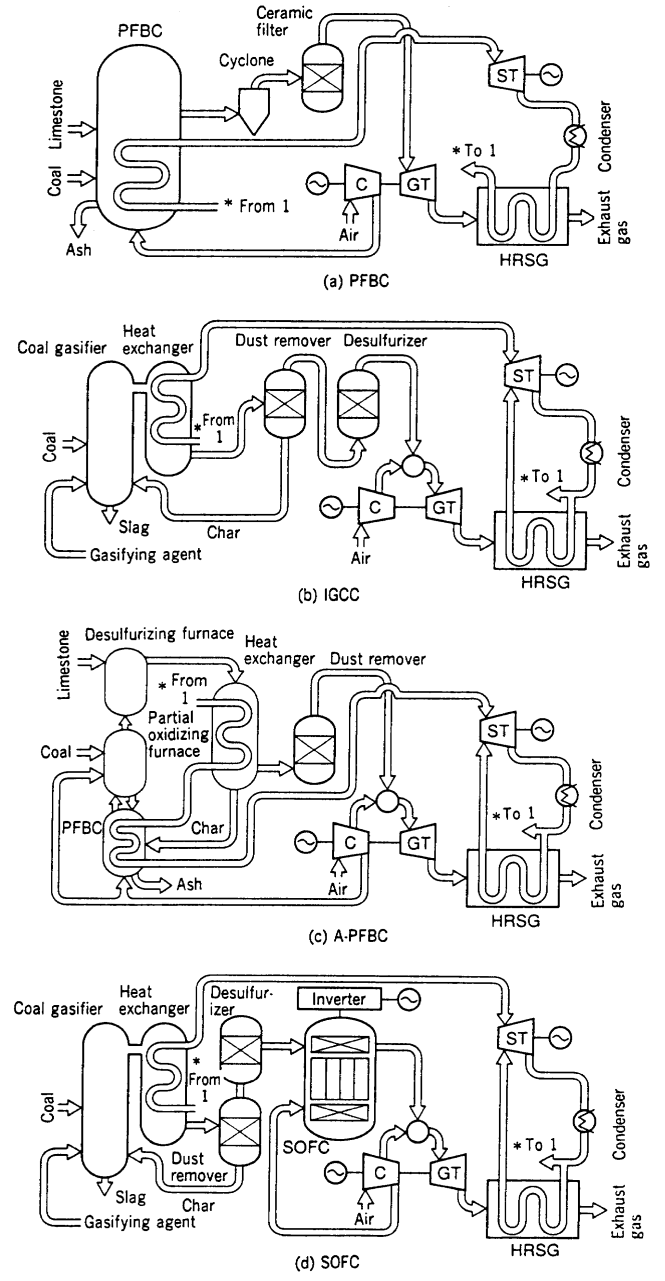

Fig. 1 Flow schemes of various coal power plants
System flow of new power plant using coal aiming at higher efficiency of plant is shown.

SOFC and gas turbine, a thermal efficiency of 55 % can be attained[3].

Since SOFC consists of multilayer ceramic, it is sensitive to variations in temperature, but durability can be improved by approximating the coefficient of thermal expansion of each ceramic layer of the SOFC cell. At present, SOFC elements are under development to prepare for mass production, and MHI has developed for the first time technologies for a solid-forming and sintering substrate, a fuel electrode, a solid electrolyte, and an interconnector. The SOFC production technology now under development is superior in economy.

5. Conclusion

Advanced utilization technology of coal as a clean and high

efficiency fuel is considered to be one of the key technologies for energy and environmental conservation in the next generation.

In the future, MHI will develop increasingly unit devices, target optimization and simplification as a system, strongly promote technical development to satisfy customers' needs, and wish to contribute to development of a more affluent society.

References

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