

Overview of Integrated Coal Gasification Combined-cycle Technology Using Low-rank Coal



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Mitsubishi Heavy Industries, Ltd. (MHI) has been promoting the development of integrated coal gasification combined-cycle (IGCC) systems using its unique air-blown gasification technology. MHI has already accomplished 250MW IGCC demonstration plant and is planning next commercial plant. In order to meet the market needs for future energy, it is necessary to use sub-bituminous, brown, and other low-rank coal, none of which are currently widely used. This paper focuses on low-rank coal, especially brown coal, and describes the development status of highly efficient brown coal drying technology, which is crucial for highly efficient power generation applications. This paper also presents an overview of brown coal-fired IGCC systems.

1. Introduction

Due to an increasing demand for energy, thermal power generation is required to play a more important role. Because we cannot depend only on natural gas and oil as fossil fuel, we will have to use coal, which is abundant and widely available at stable prices. About half of the world's coal resources are low-rank coal such as sub-bituminous and brown coal. However, because of their high moisture content and high spontaneous combustibility, they are difficult to be handled and have not been widely used.

In fiscal year 2010, Mitsubishi Heavy Industries, Ltd. (MHI) launched the Research on Highly Efficient Brown Coal Drying System project (Japanese national project) with direction and financial assistance from the Agency for Natural Resources and Energy of the Ministry of Economy, Trade, and Industry. The project is intending to improve the efficiency of power generation dramatically by developing the system that can dry brown coal with significantly less energy than before and applying the system to integrated coal gasification combined-cycle (IGCC) systems. This will contribute to a significant reduction in CO₂ emissions in coal fired power plants. The system can also be applied to the production of chemicals using brown coal gasification technology and is expected to expand the range of possibilities for brown coal applications significantly.

2. Worldwide Approaches to Low-rank Coal

2.1 Global coal resources

Each country has a different method of classifying coal types. In general, coal is classified in descending order of heating value and degree of carbonization to anthracite, bituminous, sub-bituminous, and brown coal. In Japan, for example, coal is classified by heating value according to the Japanese Industrial Standards (JIS), as shown in **Table 1**. **Figure 1** shows the breakdown of recoverable resources in each coal type. About half of all coal resources are low-rank

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coal such as brown and sub-bituminous coal, which are found in large quantities in Australia, Indonesia, the United States, Europe, and China. Although brown coal is abundant, its heating value is low (Table 1) because the half of its weight is moisture. Australian brown coal contains about 60% moisture.

Because of its low heating value, little low-rank coal is currently traded on global markets, and most of it is consumed only at mine sites. Existing brown coal-fired thermal power plants have low power generation efficiencies of around 30% due to the latent heat loss caused in the coal drying process, because of its high moisture content. This generates high rates of CO₂ on the order of 1.1 to 1.2 kg-CO₂/kWh, about 1.3–1.5 times as much as that of bituminous coal-fired plants. This is a major issue to be addressed when using brown coal.

Table 1 Coal Classification in Japan (JIS M 1002-1978)

Classification		Heating value (revised dry ash-free basis) kJ/kg (kcal/kg)		Fuel ratio	Caking property
Coal quality	Category				
Anthracite (A)	A1	-		4.0 or greater	Non-caking
	A2				
Bituminous coal (B, C)	B1	35,160 or greater	(8,400 or greater)	1.5 or greater	Strong-caking
	B2			Less than 1.5	
	C			-	
Sub-bituminous coal (D, E)	D	33,910 – 35,160	(8,100 – 8,400)	-	Caking
	E	32,650 – 33,910	(7,800 – 8,100)	-	Weak-caking
Brown coal (F)	F1	30,560 – 32,650	(7,300 – 7,800)	-	Non-caking
	F2	29,470 – 30,560	(6,800 – 7,300)	-	Non-caking
		24,280 – 29,470	(5,800 – 6,800)	-	

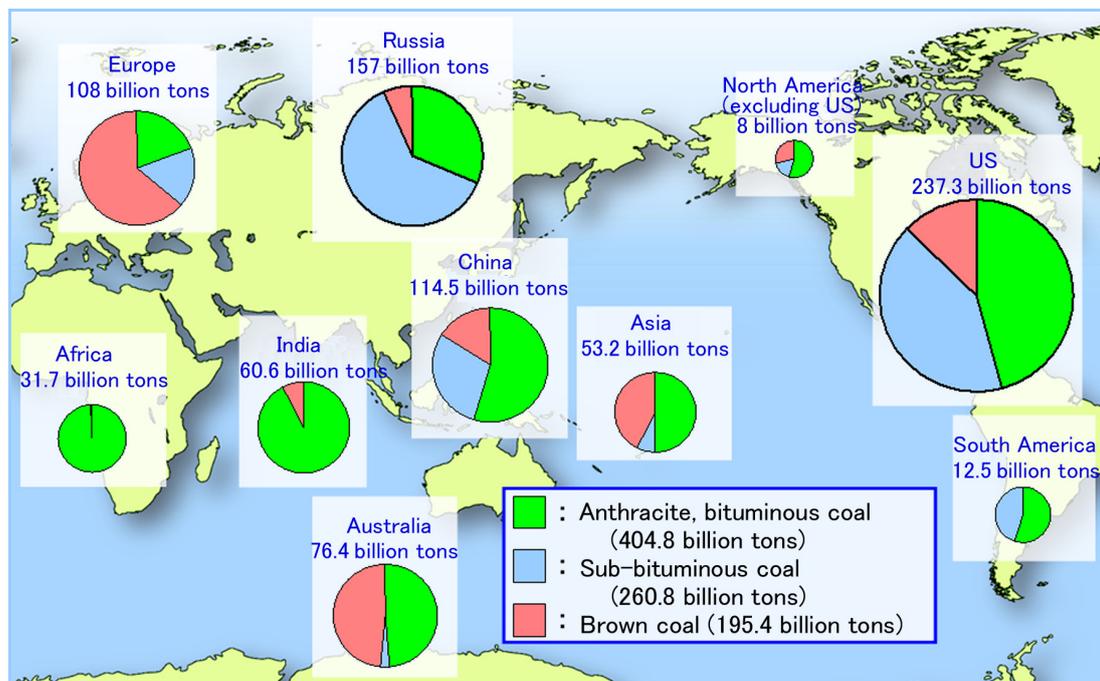


Figure 1 World coal resources

Source: WEC, Survey of Energy Resources 2010

2.2 Overview of brown coal drying technology

In order to increase the use of brown coal, the technology to dry it efficiently in large quantities is required. **Table 2** shows the technologies that could be used to dry brown coal currently in use or under development.

Table 2 Comparison of brown coal drying technologies

Item	Beater mill	CITD	STD	Steam fluidized bed
Method	Direct	Indirect	Indirect	Direct
Status of practical use	Brown coal-fired boiler (direct heating)	For briquette production	For coke ovens	Under development
Capacity enhancement	For boilers: Suitable For IGCC: Unsuitable	Possible	For coke ovens: Suitable For IGCC: Suitable or possible	Suitable
Latent heat recovery	Unsuitable	Possible	Possible	Suitable

Beater mills are widely used in existing brown coal-fired thermal power plants. They use high-temperature flue gas extracted from the boiler furnace to the pulverizer to dry the coal directly and convey it to the boiler (direct heating). Beater mills are not suited to latent heat recovery and have safety problems if a bin system is used. A coal-in-tube dryer (CITD) is a dryer composed of a shell with tubes inside. A CITD employs indirect heating in which the coal inside the tubes is dried by the steam supplied to the shell. Although this type of dryer is widely used for briquette production in Europe and other parts of the world, it has a capacity of only about 10 t/h. A steam tube dryer (STD) also uses indirect heating and the coal in the shell is dried by the steam inside the tube. STDs are used for pretreatment to adjust the moisture content of coking coal in coke ovens. They have relatively large capacities but have generally not been used for brown coal. A steam fluidized bed is a type of dryer that uses steam as the fluidization medium. It is suitable for scaling up to higher capacities because of its high heat transfer rate and it also lends itself to latent heat recovery. MHI and other manufacturers in Germany are currently developing steam fluidized bed dryers.

Existing brown coal-fired thermal power plants are using beater mills. While they are capable of drying high-moisture coal using high-temperature gas from the boiler furnace; latent heat generated by the evaporation of coal moisture is lost without being used effectively. This reduces the boiler efficiency, leading to a reduction in power generation efficiency.

Similarly, in IGCC systems, if flue gas or exhaust heat from a gas turbine was used as the heat source to pulverize and dry coal before feeding it into a gasifier, the loss of latent heat in the exhaust gas during coal pulverization and the loss of effluent in desulfurization equipment would increase significantly, causing reduction of plant output.

Therefore, the key to improving the efficiency of brown coal-fired power plants is developing effective methods of using the latent heat generated in drying the moisture in brown coal.

3. Development of Highly Efficient Brown Coal Drying Technology

3.1 Overview of the highly efficient brown coal drying system

Figure 2 is a flow diagram of the brown coal drying system proposed by MHI. Brown coal is fed from a raw coal bunker, crushed to an appropriate size by a crusher, and then transferred to a dryer. The steam dried coal is then cooled and fed to IGCC facilities. Dust is removed from the steam generated from the coal. Some of this steam is recompressed by a steam compressor and used as the heating steam in the dryer. This approach permits recovery of the latent heat of evaporation.

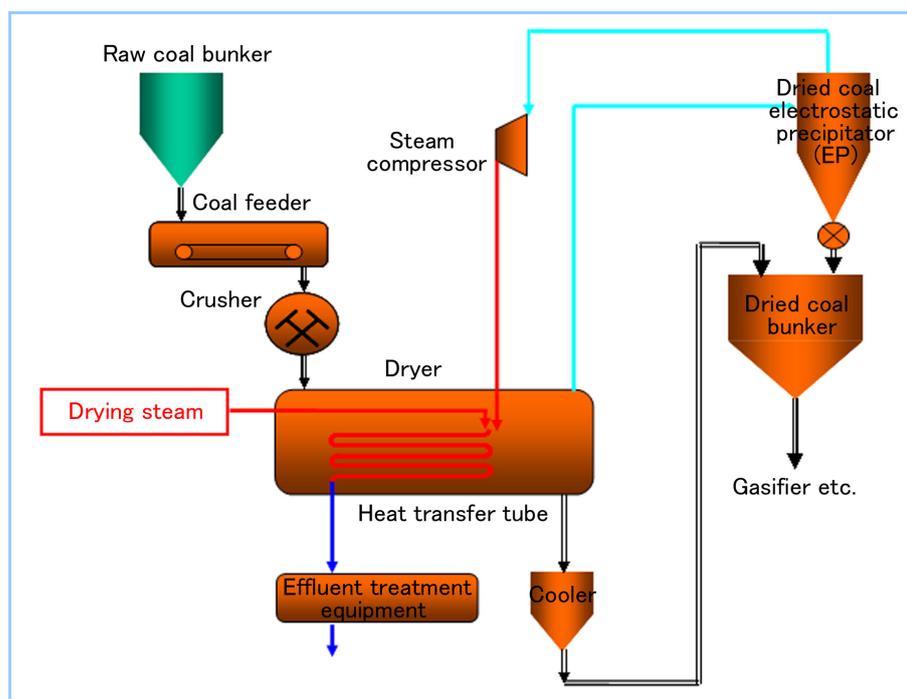


Figure 2 Schematic diagram of brown coal drying system

3.2 Research overview

MHI first completed an in-house research project in fiscal year 2009. Since fiscal year 2010, MHI has been working in conjunction with the Japan Coal Energy Center on the national Research on Highly Efficient Brown Coal Drying System project.

In fiscal year 2010, MHI completed the design, manufacture and construction of a process development unit (PDU) in March and will start PDU testing in fiscal year 2011. **Figure 3** shows an external view of the PDU. MHI also intends to install an additional system to recover latent heat by recompressing the generated steam and to conduct a verification test of the entire system in fiscal year 2011.



Figure 3 Process development unit for 10-t/day coal drying process

4. Low-rank Coal-fired IGCC

4.1 Characteristics

Figure 4 is a schematic diagram of the IGCC integrated with the brown coal drying equipment described above.

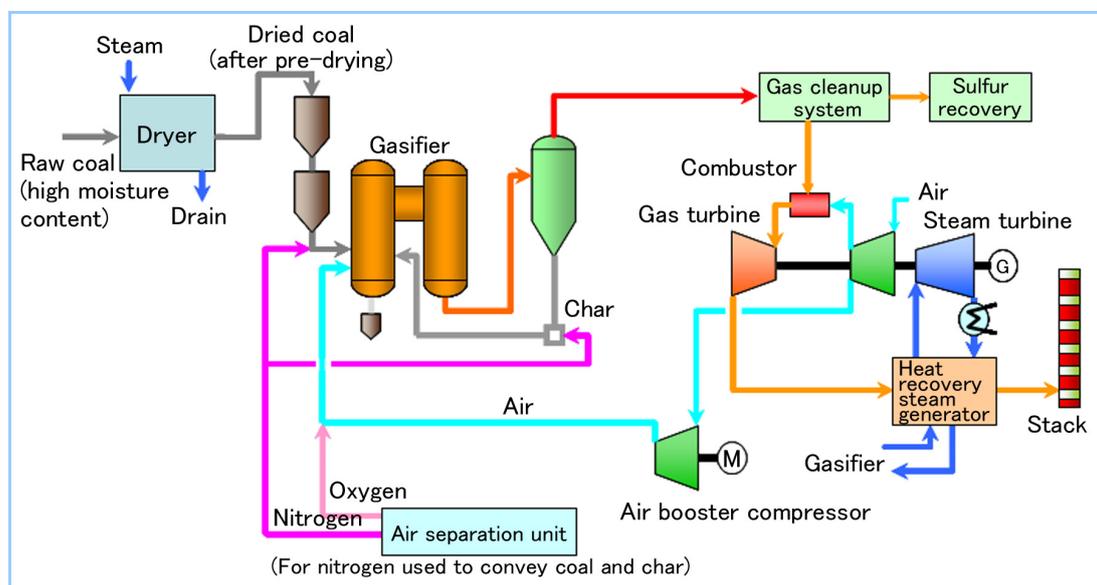


Figure 4 Schematic diagram of low-rank coal-fired IGCC

In this system, brown coal is first pre-dried with steam in the drying equipment. Coal gasification and gas cleanup then take place in exactly the same system configuration as in a bituminous coal-fired IGCC unit, followed by power generation using gas and steam turbines. Therefore, the air-blown IGCC system that has been tested with the IGCC demonstration plant can be used as is once the pre-heating is complete.

Despite its high moisture content of 50–60 wt%, brown coal is more easily gasified than bituminous coal because it has a low fuel ratio (the ratio of fixed carbon to volatile matter) of around 1. Furthermore, brown coal is suitable for gasification because it usually shows a relatively low ash melting point.

4.2 CO₂ reduction using low-rank coal-fired IGCC

Figure 5 shows the approximate net power efficiency and CO₂ emission rate of a brown coal-fired IGCC plant on a scale comparable to that of a utility plant. Compared with brown coal-fired thermal power plants currently in operation, the power generation efficiency of the IGCC is dramatically higher because of the state-of-the-art, high-efficiency gas turbine used. In addition, the IGCC plant can dry brown coal more efficiently by recovering latent heat and thereby further improve the power generation efficiency while reducing the CO₂ emission rate.

Moreover, the IGCC system discharges clean exhaust gas and can reduce the volume of ash by forming it into slag. Replacing the existing plants to the IGCC system has great advantages in terms of environmental friendliness and operational efficiency.

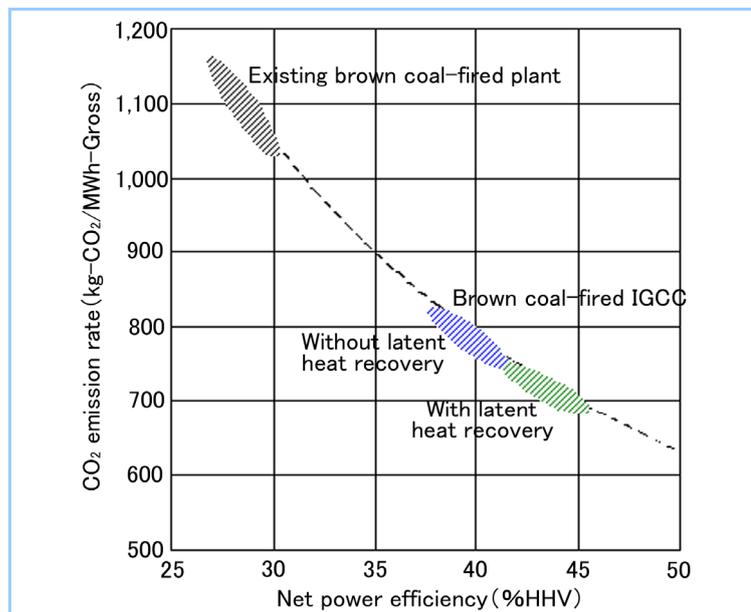


Figure 5 Net power efficiency and CO₂ emission rate of brown coal-fired power plant

5. Conclusions

The development of a low-rank coal-fired IGCC system is an important step in reducing CO₂ emissions which contribute to the greenhouse effect. IGCC shows great promise as a means of effectively using low-rank coal, which is abundant although not widely used. Practical, efficient low-rank coal-fired IGCC systems require the highly efficient drying technology described in this paper and the optimization of the entire system.

We are committed to proving the highest level of technology to meet our customers' needs based on our knowledge of how to handle low-rank coal and our established expertise in air-blown IGCC technology. In doing so, we will contribute to solving energy supply and global environmental problems.

References

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