Clean Processing and Utilization of Coal Energy

CHEN Qing-ru(陈清如), WANG Hai-feng(王海锋)

(*School of Chemical Engineering and Technology, China University of Mining and Technology, Xuzhou, Jiangsu 221008, China*)

Abstract: The dominant status of coal on the energy production and consumption structure of China will not be changed in the middle period of this century. To realize highly efficient utilization of coal, low pollution and low cost are great and impendent tasks. These difficult problems can be almost resolved through establishing large-scale pithead power stations using two-stage highly efficient dry coal-cleaning system before coal burning, which is a highly efficient, clean and economical strategy considering the current energy and environmental status of China. All these will be discussed in detail in this paper.

Key words: coal; clean processing; dry beneficiation; separator; energy utilization

CLC No.: TD849, TD92 **Document Code:** A **Article ID:** 1009−606X(2006)03−0507−05

1 INTRODUCTION

China is abundant in coal resources, with 1000 billion tons of coal reserves. Coal accounts for 70% in production and consumption of the primary energy and will still be the main energy source for the nation in a medium or long term. In 2003, China's coal output was in excess of 1.6 billion tons accounting for 74% in the total production of primary energy. Because the reserving characteristic of fossil energy in China is "abundant coal, little oil, scarce natural gas", by 2020, the energy structure of China will be developed in pluralism: even if the proportion of coal in primary energy will be decreased down to around 60%, coal output will still be up to 2.5 billion tons. Although regenerated energy (hydro-energy, wind energy, biomass energy, solar energy, etc.) is being developed rapidly, it will not account large in the share (except water and electricity). The share of nuclear energy (fission) is estimated optimistically to not more than 5% and the dispute is relatively great. Quite a few industrial and civil liquids, gaseous fuel can be converted from coal and many chemical raw materials can be stemmed from coal. Because the conversion of energy structure is a very long process, it will take about one hundred years to increase the share of a new energy from 1% to 50%. According to the development level of science and technology of energy presently, although every country has paid much attention to the renewable energy sources and other new types of energy with rapid development, they only serve as a supplement to traditional energy because absolute amount of these energies are very small. According to national conditions of China, the dominant position of coal will not change within 50 years (Table 1). So, if coal can not be realized in highly-efficient and clean utilization, it will not only cause the enormous resource wasting and environmental pollution, but also seriously threaten the sustainable development of economic construction of China in the future.

Table 1 Prediction of energy structure of China in succeeding 50 years (%)

Energy	Year			
	2000	2010	2030	2050
Coal	73.67	68.22	54.05	48.6
Petroleum	15.72	14.91	13.77	5.0
Nature gas	2.68	4.15	6.10	5.0
Water energy	7.36	9.24	9.87	19.4
Nuclear energy	0.46	3.31	13.47	16.0
New energy	0.10	0.17	2.75	6.0

2 UTILIZATION OF COAL AND ENVIRONMENTAL POLLUTION

Coal has caused the serious environmental pollution while making enormous contributions to national economic development. China is a typical smoke type air pollution country, national SO_2 emission was 21.59 million tons in 2003, ranking first in the world. The area covered by acid rain has already exceeded 30% of the total territory. China's CO_2 emission is 1/7 of the world, up to 1336 million tons, occupying the second place. China's emission amounts of SO_2 and smoke in the past ten years are listed in Fig.1[1].

In the meantime, little attention is paid to the research and development of processing and

Received date: 2005−10−07, **Accepted date:** 2005−12−18

Biography: CHEN Qing-ru(1926−), male, native of Hangzhou City, Zhejiang Province, Ph.D., academician of Chinese Academy of Engineering, research in mineral processing and clean coal technology.

transforming in China. Only less than 30% of coal in China is processed annually, at present. Processing capacity will be much insufficient compared to the increase of coal output. In the coal consumption structure of China, the power coal accounts for more than 80%, but only 14% power coal is prepared while most of coal is burned out directly without beneficiation. This will not only cause the serious environmental pollution (such as smoke, sulfur dioxide and acid rain), it has also resulted in serious economic losses. According to the "2001 Technological Consultation Research Paper of Advanced Energy" edited by the Chinese Academy of Engineering, in China, 85% of CO_2 and SO_2 emission, 70% of the smoke and 60% of NO_x come from coal burning (Table 2), and the economic losses due to air pollution in the country account for 3%~7% of national GDP. Low percentage of processed coal, outdated coal-fired technology and equipment cause that the energy consumption of China's main industrial products is 20%~60% higher than that of the advanced countries, energy efficiency being only 34%, which is 10% lower than that of the advanced countries.

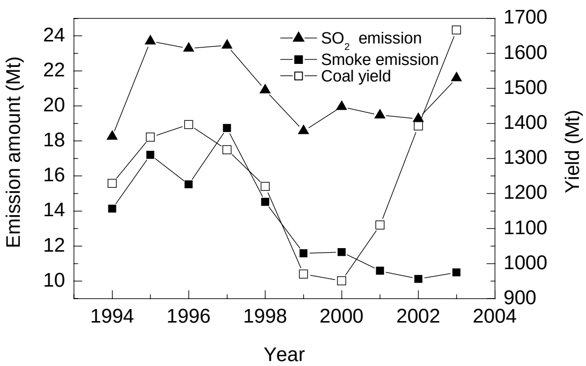

Fig.1 Emission amounts of SO_2 and smoke in recent years in China

3 CLEAN COAL STRATEGY OF CHINA

Implementing China clean coal strategy, namely, establishing large-scale pithead power stations using two-stage high efficiency dry coal-cleaning system before coal burning with Chinese characteristics, we must transform and promote the traditional industry to adopt advanced technology. Because 90% of the coal resources are in northwest arid area, as little as possible or even no water should be involved in the coal preparation technology to save the water resources and decrease operating cost and investment of the complicated huge system of product dewatering and coal slurry treatment systems which are usually required in wet coal beneficiation.

3.1 Highly-efficient Coal Dry Beneficiation Technology

Establishing large-scale pithead power stations with Chinese characteristics should adopt the flow chart including two-stage highly efficient coal dry beneficiation system as follows:

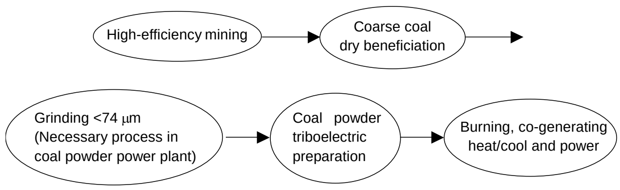

Fig.2 Multistage dry coal separation process of large-scale pithead power station

The critical technologies in this flow chart are coarse coal dry beneficiation and powder coal dry triboelectric preparation before burning.

(1) Coarse coal dry beneficiation.

Two kinds of coarse coal (50~60 mm) dry beneficiation are suitable to China. The first one is coal dry beneficiation with air-densified medium fluidized bed as shown in Fig.3, which features a wide range of beneficiation density (1.3~2.2 g/cm^3), high precision (E_p≈0.05 g/cm^3) and adaptability to prepare all kinds of coals. This equipment has been commercially used in China[2–9]. The second is a kind of pneumatic beneficiation with the FGX compound dry separator which is applicable to beneficiate 6~50 mm size of easily separated coal for removing gangue. A schematic FGX separator is presented in Fig.4. This is an economical means to reject high ash rock for upgrading low rank coals and can significantly reduce transportation costs and improve the economics of the conventional wet preparation plants, and it has been popularized in China[8–10].

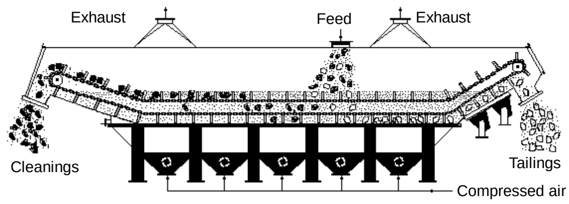

Fig.3 Schematic diagram of separator with air-densified medium fluidized bed

(2) Coal triboelectric preparation technology for <1 mm pulverized coal.

Coal is comminuted down to 320 mesh (0.043 mm) to fully liberate the embedded minerals. In

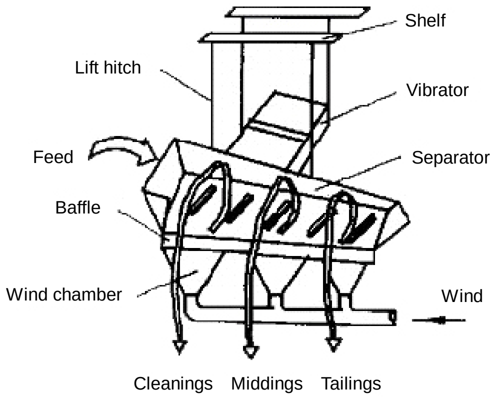

Fig.4 Schematic diagram of FXG separator

triboelectric separation, a powder material is charged either positive or negative, depending on its surface electric properties, as a result of wall friction or particle–particle collision in an air flowing at high velocities. When entering a high voltage electrostatic field, the particles with opposite charges move to the opposite electrodes, achieving the desired separation. The triboelectric separator is schematically shown in Fig.5. This kind of technology can be used to produce low ash and high heat value fuel which is supplied to power plant for the factory boiler and steel mill for the iron-smelting blast furnace, or produce ultra-low ash materials coal to use for yielding such material of coal-based carbon as high-quality activated carbon, etc.

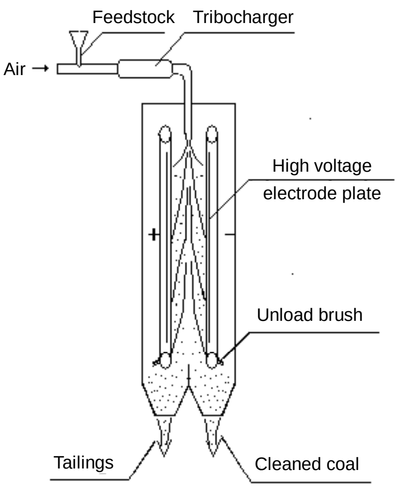

Fig.5 Schematic diagram of separator

Coal powder produced by triboelectric preparation can be adjusted according to the quality of raw coal and requirement of boilers in power plants. Product ash content of 8% and sulphur content of 0.5% with yield more than 80% can be obtained by using this technology. Tailing coal with high ash content can be utilized on the spot. All these indices can meet China's requirements for control of pollutant emission. This technology is suitable to new power station setting up and technology innovation of old power stations. If the content of organic sulphur of the coal to be processed is high, e.g., $S_{o,d} \geqslant 1\%$ in some collieries, the circulating fluidized bed combustion or flow-gas desulphurization device can be used to the treatment of high-sulphur coal. And this technology is extensively addressed elsewhere[11,12].

At present, wet coal preparation technologies still occupy a leading position in coal preparation industry. Coal prepared by wet washery is usually used to supply to power plant, which can also realize clean and highly-efficient utilization of coal, but needs a large amount of circulating water as well as groundwater in wet coal processing. The prepared coal products require numerous dewatering and complex slurry water treatment systems and equipments, so, wet coal preparation technologies are unsuitable to be adopted in a large-scale pithead power station, especially in arid northwest area that has abundant coal resources.

3.2 Establishing Large-scale Pithead Power Stations

Installed power-generating capacity was 390 million kilowatts in China by the end of 2003 with 1905 billion kW·h, and 74% of it relied on coal-fired power plants with 83% of the total power yield. About 900 million tons of coal was used to generate power accounting for 53.5% of the total consumption of coal. By 2020, the installed power-generating capacity of China will exceed 900 million kW, while coal-fired power-generating capacity will account for more than 65% and its electricity yield will exceed 75% and power coal consumption will exceed 1.75 billion tons, being about 70% of the total amount of coal consumption.

In the year of 2002, 91.8% of American coals with average ash content lower than 9% are used for electricity generating, but the average ash content of coal used for power generating in China was up to 28% in 2003. In China most power plants are far away from collieries, and usually long distance transportation for power plant coal supply is needed. High ash content raw coal causes the environmental pollution and high transportation cost as well.

Establishing large-scale pithead power stations means that after being processed into low ash, low sulphur and high heat value coal powder by using highly-efficient dry beneficiation near the colliery pithead, coal is supplied to boilers for generating electricity followed by transmitting to consumers via high voltage. And this will avoid remote transport, developing co-generating heat/cool and power according to the condition in the mean time. Tailings can be comprehensively utilized in colliery, which reduce the environmental pollution of mining area greatly. This will be optimum, most economic and cleanest energy strategy for the production and consumption of coal resource in China.

In summary, as the biggest coal production and consumption country in the world, China must account on advanced technology and implement the strategy of large-scale pithead power stations to realize clean, highly-efficient and economic utilization of coal. It also has very important strategic meanings for coal industry reform, economizing coal resources, promoting ecological environment protection and realizing sustainable development.

3.3 Economic, Environmental and Energy-saving Benefits of Pithead Power Station by Adopting High-efficiency Coal Dry Beneficiation

At present, coal-fired power plants in China mostly burn raw coal. As strengthening the control on SO_2 emission of generating electricity with coal constantly, China has established and is establishing a large quantity of desulphurization facilities in coal-fired power plants. Among various kinds of desulphurization methods, adding desulphurization additives to boilers is widely used. However, this will influence the coal heat value and increase the coal consumption. It also generates SO_2 at high temperatures while the capital expenditure of flow-gas desulphurization devices after burning and expenses of operating cost are relatively high. For example, 600000 kW coal-fired units of power plant of Huangpu in Guangdong Province will adopt the wet limestone–gypsum flow-gas desulphurization (FGD) method with foreign equipments, and the plant will start to run in 2005. It is said that 16770 t/a of SO_2 emission can be reduced at an estimated investment of ¥297 million. In the mean time, the FGD gypsum generated by wet limestone–gypsum flow-gas desulphurization process will pollute environment again.

With two-stage highly-efficient coal dry beneficiation technology, desulphurization capital expenditure for getting rid of one ton SO_2 is only 1/7 compared to wet limestone–gypsum flow-gas technology. Furthermore, its operating costs are much lower. After coal being prepared, a large amount of ash is removed, and generally the ash content or moisture of the steam coal is reduced by 1% each time, its low-order heat value increases about 0.37 MJ/kg. If supplying to the power plants with the high-quality steam coal (ash content is for 15%), now the average ash content of national steam coal will be dropped from 28% to 15%, the low heat value of steam coal increases about 4.8 MJ/kg, the coal consumption will save to 96.2 grams coal per kW·h for electricity generating. It is 19% lower than 498 grams per kW·h in 2002, and efficiency of energy-saving is very remarkable, tailing coal of ash content up to 70%~80% can be used to make construction materials, filling mines, building the road, etc.

So, the operators of power plants should change their idea of using the inferior coal to generate electricity fundamentally. The coal power stations should use the high-quality steam coal to generate electricity, though the coal price rises to some extent, but it improves the thermal efficiency of the boilers and decreases the amount of coal consumption, decreasing fly ash as well as equipment maintenance and environmental pollution. The overall economic and environmental benefits are very considerable. A coal mine enterprise produces the low ash, low sulphur and clean coal with high heat value, the price depends on the quality, the price is raised rationally, and the colliery has made very good economic benefits at the end.

3.4 West–East Electricity Transmission Project

It is the great decision-making of energy construction in China to realize “West–East Electricity Transmission Project”. To set up large-scale pithead power stations with Chinese characteristics, it is the optimum choice to realize “West–East Electricity Transmission Project”, the combination of coal and electricity, comprehensive development and appropriate scale of operation, which have complementary advantages.

The western region of China with abundant coal resources is the base of energy supply of China, but water resource shortage has restricted the development of this seriously. In light of this when planning rational processing and utilizing of coal resources in the western areas of China, this contradiction must be considered well. “Three West” (Shannxi, Shannxi and Inner Mongolia provinces) is the main coal energy base of China, transportation of coal by railroad mostly is restricted in the past due to insufficient transportation capacity. If the coal-generated electricity on the spot in the western areas can be transmitted to the East of China, it will not merely alleviate the load of railway transportation and gain enormous economic benefits, and will also have very good environmental benefit. Practice has proved that transmitting electricity is lower in construction investment and operation costs and shorter in construction period than those of transporting coal.

4 CONCLUSIONS

Based on the above discussion and the energy situation of China, some conclusions are drawn as follows:

(1) As one of important energy sources in China, the dominant status of coal will not be changed in the middle period of this century, and it will still be the major energy source in a medium or long term in China.

(2) Implementing China clean coal strategy, namely, establishing large-scale pithead power stations using two-stage high efficiency dry coal-cleaning system before coal burning with Chinese characteristics can effectively realize coal conversion and utilization with high efficiency, low pollution and low cost, and make coal be converted into clean electric energy because transmitting electricity is superior relatively to transmitting coal, which is beneficial to the sustainable development of energy industry of China.

(3) Effective desulphurization and deashing of coal before burning can increase coal heat value, improve combustion efficiency, save coal consumption, decrease the capital expenditure of desulphurization and operating cost, and reduce the pollution from SO_2.

REFERENCES:

[1] Reports of Chinese Environmental Status [R]. Beijing: State Environmental Protection Administration of China, 1995–2004.

[2] Chen Q R, Yang Y, Tao X X, et al. 50 t/h Coal Dry Cleaning Demonstration Plant with Air Dense Medium Fluidized Bed [A]. Fluidization '94 Science and Technology Conference Proceedings, Fifth China–Japan Symposium [C]. Beijing: Chemical Industry Press, 1994. 381–389.

[3] Chen Q R, Yang Y, Yu Z M, et al. Dry Cleaning of Coarse Coal with Air Dense Medium Fluidized Bed at 10 Tons per Hour [A]. Morsi B. Eighth Annual International Pittsburgh Coal Conference Proceedings [C]. Pittsburgh, Pennsylvania: University of Pittsburgh, 1991. 266–271.

[4] Wei L B, Chen Q R, Liang C C. Study on the Mechanism of Coarse Material Separation in the Air-dense Medium Fluidized Bed [J]. J. China Univ. Min. Technol., 1996, 25(1): 12–17 (in Chinese).

[5] Luo Z F, Chen Q R. Effect of Fine Coal Accumulation on Dense Phase Fluidized Bed Performance [J]. Int. J. Miner. Process., 2001, 63(4): 217–224.

[6] Chen Q R, Wei L B. Coal Dry Beneficiation Technology in China —The State-of-the-Art [J]. China Particuology, 2003, 1(2): 52–56.

[7] Beeckmans J M, Goransson M. Coal Cleaning by Counter-current Fluidized Cascade [J]. CIM Bull., 1982, 75: 191–194.

[8] Blagov E S. Hand Book of Coal Preparation [M]. Moscow: Petroleum Press, 1974. 331–351 (in Russian).

[9] Leonard J W. Coal Preparation, 4th Ed. [M]. New York: AIME, 1979. 1110-1132.

[10] Yang Y S. The Development and Application of the FGX Compound Dry Coal Separation System [J]. J. China Coal, 2003, (Suppl.): 11–18 (in Chinese).

[11] Chen Q R, Yang Y. Triboelectric Beneficiation Technology in front of Burner in the Power Plant of Coal Powder [A]. Zhang B M. Proceedings of Second International Symposium on Clean Coal Technology [C]. Beijing: China Coal Industry Publishing House, 1999. 271–276.

[12] Zhang X X, Gao M H, Ma R X, et al. New Method of Desulfurization in Power Station—Online Desulfurization of Fine Coal Pre-combustion [J]. Energy Environ. Protection, 2004, 18(5): 1–4 (in Chinese).