C-3.1.2 Studies on Popularization of Techniques for Controlling the Emission of Precursors of Acidic Substances in Air

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Abstract In our studies, to enhance effective utilization of low-grade coals with high sulfur content and to control pollutant emissions from the sources in the region of Chongqing in China, a coal-biomass briquette technology and a new dry cleaning-coal technology by mean of static electricity were performed to separate the coal from pyrite, ash and various other minerals were developed in Chongqing. As the main results of the combustion experiments, coal-biomass briquette has the high desulfurization efficiency and lower ignition temperature and higher combustion efficiency than the local coal briquette. The locations, investment, production cost, market research, economical efficiency and pollutant emission control regarding the new manufactories in the future were investigated. It is revealed that the coal-biomass briquette technology and the static electricity dry cleaning-coal technology researched were simple, economical, and efficient and were considered to be very applicable for air pollution control of coal combustion in China.

Key Words Acid rain, Chongqing of China, Coal-biomass briquette, desulfurization, Dry cleaning-coal technology

1. Introduction

With the impressive development of industrialization and economy, and on the increase of coal consumption in China, the air pollution and acidic precipitation caused by coal combustion is one of the serious environment problems. The coal consumption is about 1.1billion tons. The low-grade coal is also used, in which contains high sulfur and ash content, and its calorific value is even lower than 4,000 kcal kg^{-1}. The dust and SO_2 emitted from the coal combustion was 17.0 million tons in 1992, 14.0 million tons in 1994. One of typical regions is Chongqing City, a new economic, culture and political center located in southwestern China with the population of ca. 3,040 million peoples and the wide-area of ca. 820,000 km^2. The atmospheric conditions in Chongqing are usually stagnant in the lower layer with weak winds, which should favor wide-scale accumulation of the atmospheric pollutants even during the daytime together with the special Sichuan basin geography. Since the city is the largest SO_2 emitter from the local combustion sources of low graded raw coal (S = ca. 2~6%, ash = ca. 25~40%) [1] for the activities of household use and industrial purposes, these pollutants have destroyed ecological system and brought big economic loss of the agriculture and the forest, and the health damage.

For these reasons, the desire for the introduction of cleaning-coal technology is extremely high, and China government demands the technical support and fund for developing it from Japan. The development for the coal-biomass briquette technology and a new static electricity dry cleaning-coal technology is one of the China-Japan Cooperation projects of the Global Environment Research Programs of Global Environment Department, Environment Agency, Japanese Government, from FY

1997 to FY 1999.

In this study, we are introducing the effective coal-biomass briquette technique2~6 to reduce the emission of SO_2 and other pollutants lead by coal combustion sources of “lower-layer air mass”, which mean the sources from household use of inhabitant and small boilers rather than ones from industries. Coal-biomass briquette is produced from pulverized raw coal, biomass such as straw, various woody wastes and agricultural wastes (e.g. barks, sawdust, bagasse, beet pulp, rice husk etc.), and slaked lime as sulfur-fixation agent, under high roll line pressure (3~5 ton cm^{-2}). From the field surveys, we gathered the data on the physical and chemical properties, available amount and cost of raw materials such as raw coal, biomass and sulfur-fixation agent for making coal-biomass briquette. The expecting reduction rate of the emitted SO_2 was 80~90% in the preliminary tests and analytical results.

On the other hand, the coal-cleaning technique is mainly classified as two types, dry and wet. is the sink and float cleaning-coal. In the typical process of wet coal-cleaning technique, water resource and the high running cost, treatment of sludge and wastewater are necessary. Also, the coal with the particle size less than 0.3 mm, which is disposed as slurry to sedimentation basin or utilized as fuel, cannot be cleaned. Therefore, the coal-cleaning yield falls about 15%. Therefore, the development of new coal-cleaning technique to solve these problems is expected. In this study, the small apparatus and bench scale apparatus for dry cleaning coal using static electricity were developed. The dry coal-cleaning characteristic of the coal produced by China and Japan were evaluated.

2. Research Objective

As mentioned above, the objective of our studies is to develop a coal-biomass briquette technology and a new static electricity dry cleaning-coal technology performed to separate the coal from pyrite, ash and various other minerals for effective utilization of low-grade coals and integrated control for precursors of acidic precipitation from the sources of coal combustion in the region of Chongqing, China.

It were researched that the briquetting and combustion characteristics of coal-biomass briquette, sulfur-fixation and energy efficiencies, on the basis of the briquetting and combustion test results. These are so far obtained from the experiment with a testing machine installed in Hokkaido, Japan, and the investigation on the briquetting equipment set in the demonstrating plant of Chongqing. With the combustion test of coal-biomass briquette for domestic use and small and medium size boiler, desulfurizers, the Japan-China research group improved and assessed production and combustion technique of coal-biomass briquette.

At the same time, it is necessary to develop the effective techniques for reducing the emission of SO_2 and other pollutants lead by coal combustion sources and utilization of low graded raw coal (S = ca. 2~6%, ash = ca. 25~40%) in Chongqing, which mean the sources from household use of inhabitant, small boilers and ones from industries. However, typical process of wet process coal cleaning technique is the sink and float coal cleaning process in China. A water resource is necessary for this process, and cost of installation cost, sludge treatment and wastewater treatment are very high. Thus, if the treatment measure is not enough, the environmental pollution such as river contamination will be caused. For this reason, the Japan-China research group also carried out development of dry coal cleaning system using static electricity in Hokkaido, Japan. In FY1998 plan, the bench scale equipment was installed at Nantong coal mine in Chongqing. The coal cleaning characteristic of Chinese coal and Japanese coal were evaluated on the basis of separation efficiency of inorganic sulfur content and ash content, accommodation particle size range, separation efficiency of clean coal recovery. And installation cost and running cost of dry coal cleaning equipment were calculated and the feasibility of this equipment was confirmed.

3. Experimental Equipments and Methods

3.1. Coal-biomass briquette Production Process and Combustion Experiments

The properties of tested coal, biomass, and desulfurizers in the experiments are sampled in Chongqing. The coal, whose sulfur content, around 4.6 mass% (dry basis) and ash content, 15.4 mass% (dry basis) just falls into low grade coal family with high sulfur and high ash contents. It is being used in large amount in Chongqing city. The biomass used in this study is sawdust (forest waste) whose the sulfur content and volatile matter content are almost zero and 82 mass%. It has lighter impacts on environment and higher reactivity, and their mixture is able to balance these defects of the coal. As said above, the coal-biomass briquette was manufactured under quite high pressure. Its automatically continuous manufacturing test in industrial-scale production was performed as followings. The coal, biomass and desulfurizers were dried in air, and then were ground to the diameter under 2 mm. The limestone, scallop shell, calcium hydroxide and wasted admixture by-produced in gas welding industry were used as desulfurizers. Their particle diameters were in the range of 297-420μm for both the limestone and the scallop shell, 0-25 μm for the calcium hydroxide and 0-1 mm for the wasted admixture. And then, they were compressed without any binder through a couple of pressing rollers under the compression pressure of about 295[MPa] (3 ton/cm^2). The coal-biomass briquette manufactured in this way has enough strength to prevent it from breaking in transportation process and to restrain smoke and dust in combustion process. The manufacturing machine made in Japan can produce continuously such coal-biomass briquette of about 1.25 ton per hour. The coal-biomass briquettes were manufactured in pillow shape and each of them weighted about 28g.

The combustion experiments were performed in a domestic stove and an electrically heated furnace. This kind of domestic stove is being used quite popularly in China (its schematic illustration is omitted) because it is cheaper and convenient for family use. In order to compare the combustion results between coal briquette and coal-biomass briquette, the coal-biomass briquettes produced in the pilot plant were supplied to citizens and the combustion experiments in domestic stoves for family life carried out over half a year. The combustion results were investigated. Also, the particulate emissions from the combustion of both coal briquette and coal-biomass briquette were captured and compared in domestic stoves.

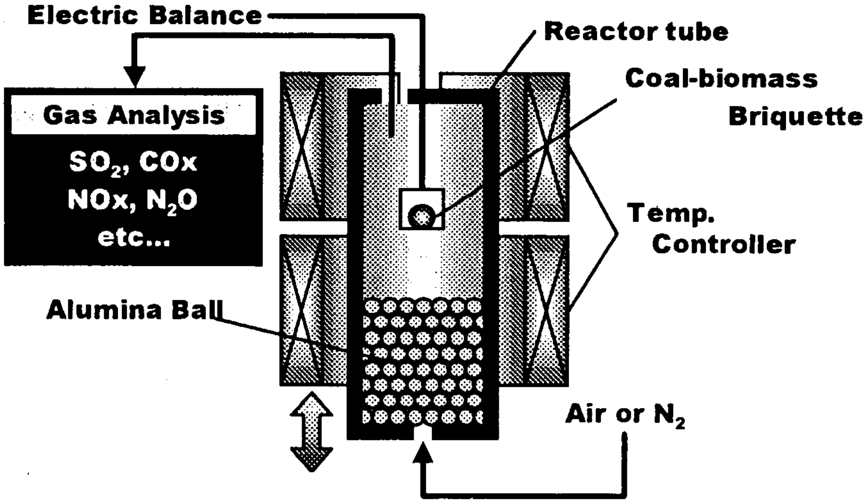

Figure 1 Experimental combustion apparatus.

The electrically heated furnace, schematically shown in Figure 1 was employed to reveal the influence of biomass on combustion and the sulfur-fixation agent characteristic by experiments. The furnace consists of temperature controllers, a digital balance, and a flue gas analyzing system. The sample was suspended by a wire linked to the digital balance and was positioned in the center of the furnace. The furnace was preheated up to a predetermined temperature, and then moved upward to heat the sample. The time concentration history of SO$_2$ etc in the furnace flue gas and the sample mass loss were continuously measured during combustion process, respectively, by using the digital balance and the flue gas analyzing system. The desulfurizing efficiency was obtained as followings:

$$\eta_{SO_x} = [1 - \alpha \times SO_{2(Ca/S=n)} / SO_{2(Ca/S=0)}] \qquad (1)$$

Where $SO_{2(Ca/S=0)}$ is the SO_2 emission from the combustion of sample without desulfurizer and $SO_{2(Ca/S=n)}$ the SO_2 emission from the combustion of sample with desulfurizers (Ca/S =n). The Ca/S represents the molar ratio of calcium to sulfur in a sample.

3.2. Description and Experiments of Dry Coal-cleaning Equipments

The experimental with static electricity, which are the small drum type of static electricity dry coal cleaning equipment installed in Japan shown in Figure 2(a), and the bench scale static electricity dry coal cleaning equipment installed at Nantong coal mine in Chongqing, which is shown in Figure 2(b). Six boxes are arranged in the bottom of the equipment to receive the production of coal and ash particles being separated. Coal and ash particles fall from the top to the drum, which is turning at the constant speed. The coals adhered on the drum with the pole fall to the seven boxes. Parts of coal scatter the boxes, too. Thus, the particles between the electrostatic field will fall into each location based on the difference of diameter, specific gravity, dielectric constant, static charge amount.

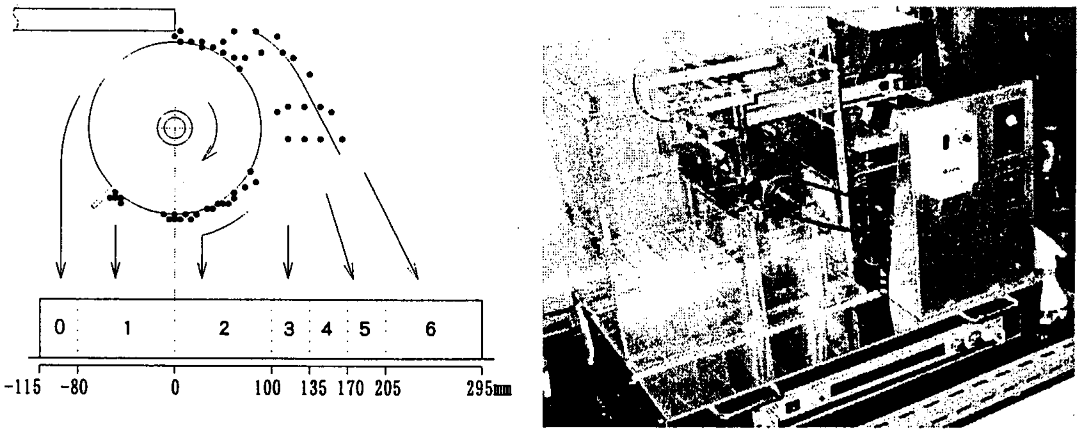

Figure 2(a) The experimental static electricity dry coal cleaning equipment.

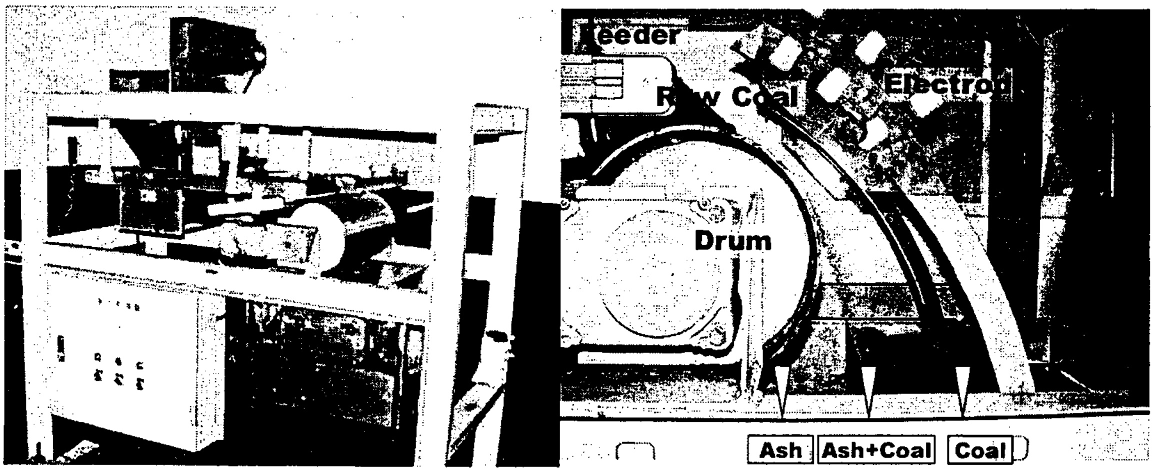

Figure 2(b) The bench scale equipment installed at Nantong coal mine of Chongqing.

Coal is supplied from the height of 10 mm above the center drum top and the quantity of feed is about 8 kg/h. In this test, the effects of drum peripheral speed, voltage and coal particle size on coal cleaning were investigated. Also, the separation efficiencies of dry coal-cleaning were evaluated based on the industry analysis, sulfur content of coal and the exothermic quantity as compared with the wet method. By the way, the dust explosion test was done before coal cleaning test in order to confirm danger of explosion by coal dust and coal particle size of lower limit decided was 0.125mm.

4. Results and Discussion

4.1 Properties of Coal-biomass Briquette

The coal-biomass briquette has strength enough to withstand ordinary handling without using any special binder. This is because its biomass may act as a binder. This action may be expected for other biomasses such as bagasse, beet pulp and rice husk similar in theoretical properties to wood waste. From microscopic observation, we found a specimen of the internal texture of coal-biomass (woody) briquette obtained by polishing. Both coal and wood grains are oriented in a direction and coal grains in a surface part of coal-biomass briquette are finer in its sizes. And the voids among coal grains are more compact with wood grains, where seem to be plastic-deformed in briquetting process. Thus, the woody constituent serves as binder in coal-biomass briquette. This action has been recognized in biomass fines such as baggase, sawdust, Kaoliang, corn stalk or husk, rice husk, beet pulp and so on, having a rheological properties similar to wood fines. Therefore, these biomasses can be expected to use as raw materials for coal-biomass briquette production. The microscopic observation of coal-biomass briquette internal structure may bring about important data for consideration on its briquetting process and the action of biomass as a binder. In our study, fine coal particles are observed on coal-biomass briquette surface. This fact tells that unlike the biomass showing large plastic deformation, the coal particles have partially been broken in the briquetting process. In case of high-pressure briquetting, it is therefore assumed that the briquettability of coal is greatly influenced by the coal strength. Of these coal grades, Nanton coal and Tianfu coal of Chongqing were mainly used to conduct a coal-biomass briquette production test in this study. The results obtained show that these belong to the group of easily briquettable coal.

4.2. Ignition and Combustion Experiments of Coal-biomass Briquette

In general, when solid fuel is heated up by preheated furnace and its temperature rises rapidly. After the fuel reaches a certain temperature, noncombustible and combustible volatiles release out, and then the combustible volatile ignites and burns. The volatile combustion leads to the solid particle combustion. Therefore, the volatile evolution and combustion will certainly give large influence on the ignition and combustion of solid fuel. In order to investigate the ignition and combustion characteristics of coal-biomass briquette, its ignition and combustion experiments were conducted. It was seen that the biomass content had obvious influence on the ignition temperature. The temperature is rapidly decreased with the accretion of biomass content when it is under 20 mass%, but its influence become vague and the ignition temperature of coal-biomass briquette go nearly to the ignition temperature of biomass if the biomass content is over 20 mass%. This could be considered as the reason why the volatile of biomass had lower ignition temperature than that of coal. Its content increase contributes the much more volatile of lower ignition temperature to a coal-biomass briquette. This makes the coal-biomass briquette to have lower ignition temperature as compared with that of coal briquette.

Moreover, The combustion characteristic of coal-biomass briquette and the influence of biomass on the characteristic were explored by the combustion experiments in electrically-heated furnace. The time histories of unburnt fraction in coal-biomass briquette combustion with different biomass additions were found. There appear two stages in the combustion process, the first stage with a rapid mass loss, and the second with a slower mass loss. These two stages can be considered to correspond to the two combustion stages, namely the volatile combustion stage and the char combustion stage. The volatile in coal-biomass briquette are evolved and burnt in gas phase around the coal-biomass briquette when the coal-biomass briquette is heated up to the ignition temperature. The char combustion doesn't occur on the surface of the coal-biomass briquette until the volatile combustion is almost finished. As oxygen diffuses from the surface towards the inside, the char burns and the flame sheet keeps moving towards the inside till the center when char is completely burned out. The char combustion accords with the shrinking-core reaction model and is controlled by oxygen diffusion through both gas boundary layer and the ash layer. It was noted that the more the amount of biomass addition was, the shorter the burnout time was. This is because the coal-biomass briquette has more volatile content than the coal briquette does. Its devolatilization enlarges the porosity in the char and makes the oxygen diffusion easier. These make the combustion rate of the coal-biomass briquette faster than the coal briquette.

The combustion experiments were performed in a domestic stove. The water temperature histories of a kettle on the domestic stove are illustrated in Figure 3. It was seen that although the tested water and fuel amounts (water is 5.7 kg and fuel 2 kg) are the same for the coal-biomass briquette and the coal briquette, the heating time of the water from 273 K to 373 K was 30 min for the former and 45 min for the later. The boiling time of the water lasted 96 min for the coal-biomass briquette and only 50 min for the coal briquette. In addition, the combustion experiments in domestic stoves for family life indicated that the averaged combustion efficiency was about 65% for the coal briquette and about 80% for the coal-biomass briquette. The around 30% of domestic fuel can be saved through changing the present coal briquette for the coal-biomass briquette.

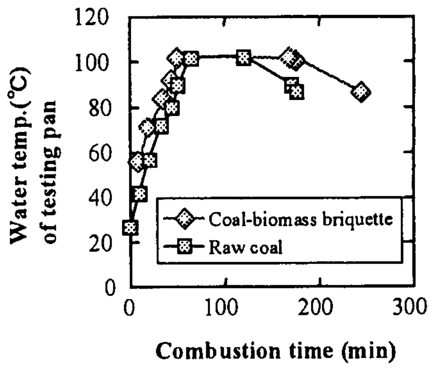

Fig.3. Combustion behavior of coal-biomass briquette and raw coal.

4.3. Desulfurization of Coal-biomass Briquette

Combustion Limestone is commonly used to capture SO_x in fossil fuel combustion processes. In our former study, a kind of typical and abundant seashell called scallop shell (aquatic waste) was developed as a desulfurizers and its desulfurization results were confirmed to be much better than limestone as well in coal-biomass briquette combustion. This is because the lager pore size on scallop shell emerges during calcination and the desulfurization reaction is able to come inside the particle of scallop shell, whereas the desulfurization reaction of limestone only comes in the near surface. This makes the difference in desulfurization capability. On the other hand, the production cost of coal-biomass briquette plays the most important role in the familiarization of coal-biomass briquette in some developing countries. The lower both the purchase price of desulfurization and the Ca/S value in a coal-biomass briquette is, the less the cost is. Therefore, in this study, a new sulfur desulfurizer from wasted admixture by-produced in gas welding industry, which contains large amount of CaO was developed to capture the SO_2 from coal-biomass briquette combustion. Its desulfurization results were investigated by combustion experiments in electrically-heated furnace. The variation of SO_2 emission in flue gas are shown in Figure 4, which were measured from the combustion of both coal briquette without any desulfurizer and coal-biomass briquette with a certain desulfurizer (Ca/S=1.5).

In Figure 4, two different parts appear in SO_2 concentration profiles. The two parts correspond to the volatile combustion and the char combustion, respectively. The area under the SO_2 concentration profile denotes the total SO_2 emission. The experimental results showed that the desulfurization occurred in the two stages of coal-biomass briquette combustion when the new desulfurizer was used. This performance is quite different from the desulfurization behavior of both limestone and wasted scallop shell in coal-biomass briquette combustion. It seemed to suggest that the new desulfurizer might have better desulfurization characteristics. Thus, its desulfurization efficiency was compared with that of the limestone, scallop shell and calcium hydroxide (with about 96% purity) here. The desulfurization capability of scallop shell in coal-biomass briquette combustion is nearly twice as high as that of limestone, which is consistent with our previous result. The desulfurization efficiency of the new desulfurizer was much higher than that of the limestone and the scallop shell, and was the same as the calcium hydroxide as well. This is because the desulfurization happens mainly in char combustion stage when limestone and scallop shell are added, whereas in both volatile combustion stage and char combustion stage when the calcium hydroxide and the new desulfurizers are added.

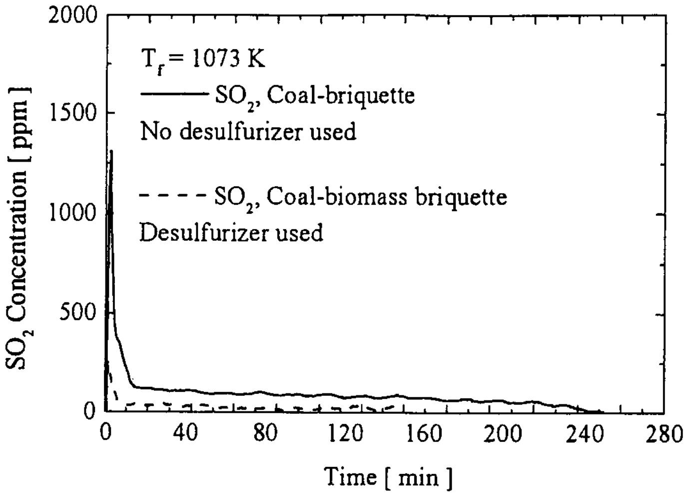

Figure 4 Time variation of SO_2 emission in flue gas.

It was known that $CaCO_3$ in limestone and scallop shell is converted into CaO at first during calcination, and then CaO reacts with SO_2 to produce $CaSO_4$. The calcination temperatures for limestone and scallop shell are about 973 K and 1023 K respectively. Under 973 K, most of volatile in coal-biomass briquette is burned out and no CaO to capture SO_2 is produced. Therefore, it should be quite clear that the desulfurizer based on $CaCO_3$ seems to be difficulty in capturing the SO_2 from volatile combustion. On the other hand, however, calcium hydroxide has a much lower calcination temperature, only about 673 K, and CaO can be produced in the volatile combustion stage to capture SO_2, which results in a higher desulfurization efficiency. For the new desulfurizer, it originally contains CaO, and is able to capture SO_2 from volatile combustion.

4.4 Feasibility Results for the Production Plant

We performed a feasibility study on the construction of a coal-biomass briquette production plant with a 200,000-ton annual production capability in the national Nanton coal mine of Chongqing. In this feasibility study, we assumed that the briquetting machine, which is the technical core, would be manufactured in Japan and peripheral equipment such as dryers, mixers, and so on would be made in China. The gross-investment frame for plant construction was estimated at 58.1 million yuan (about 8.7 million US dollars). It turns out that the total manufacture costs including the price of materials contained in coal–biomass briquettes, personnel expenses, running costs, and so on would be 213 yuan per ton, and the selling price of coal-biomass briquettes would be 245 yuan per ton. The estimated selling price is about 1.5 to 2.0 times higher than that of conventional coal briquettes or raw coal. However, the cost benefit is large and obvious, because the acid-rain damage originating with coal combustion, building loss, health damage, etc. can be reduced by the introduction of coal–biomass briquettes; they bring about improved combustion efficiency and control the effect of pollutant discharge. Moreover, our financial analysis showed that the collection period of the gross-investment for plant construction would be less than 8 years.

4.5 Characteristic of the Low-grade Coals Sampled for Coal-cleaning

Zongliangshan coal, Datong coal, Nantong coal and Taiheiyo (TABLE I) coal were used for coal cleaning tests. These coals are used as domestic fuel for a small and a middle size boiler at Chongqing city and rural site in China. The coals produced in China contain high ash and sulfur, which can result in air pollution. The particle size of coal ranges between 0.125~2.000 mm, the sample particle with less than 0.125 mm was removed due to risk with danger of dust explosion.

Before coal cleaning test, it is necessary to examine pyrite (FeS_2) content, which can emit SO_2. From the results of X ray analysis of the raw coals, quartz, calcite kaolinite as clay mineral and pyrite that is one of the main sources of acid rain were observed. If the coal particle is separated from the mineral particle in coal cleaning test, it is considered that the separation efficiency is excellent. From microphotography of raw coal (particle size 0.125~2.0 mm), pyrite (bright and white part) exists in all of coals.

Table I particle size distribution and analysis results (dry base, weight%)

Size	China coal (Chongqing and rural site)									Taiheiyo coal	
	Zongliangshan			Datong			Nantong			Raw coal	
	ratio	ash	sulfur	ratio	ash	sulfur	ratio	ash	sulfur	ratio	ash
0.000～0.125 mm	22.2	19.3	3.6	16.6	22.4	3.4	20.7	21.2	2.6	11.9	45.8
0.125～0.250 mm	12.4	21.2	4.0	10.2	20.0	3.7	12.8	19.8	2.8	8.9	32.5
0.250～0.500 mm	16.5	24.0	4.0	14.3	21.3	3.8	17.4	21.7	2.9	15.1	25.7
0.500～1.000 mm	22.7	27.3	4.1	21.9	20.7	4.2	23.0	30.4	3.4	31.7	24.7
1.000～2.000mm	26.2	37.4	7.0	37.1	28.8	5.5	26.1	43.9	3.0	32.3	29.0

For Zongliangshan coal, it is observed that both the big isolated pyrite and the fine pyrite particle exist on coal surface in microphotography. Nantong coal contains a little pyrite. And the moisture was added in coal to raise the dielectric constant of coal samples. The difference of electrical properties of clean coal and waste coal were emphasized by this method. The moisture of coal became 3% hereby.

4.6 Experimental of Small Coal-cleaning Equipment with Static Electricity Method

The effect of the drum peripheral speed on coal-cleaning was investigated. Peripheral speed of drum was set in 16.7cm/s and 33.5cm/s. Particle size of the coal is 0.250~0.500 mm, voltage is 10000V. If the peripheral speed is fast, the flying distance of particle becomes long and most of coal fell to 6th box. On this account the peripheral speed of drum was selected as 16.7cm/s.

The effect of voltage and particle size on coal cleaning was investigated. As coal particle size became big, the effect of voltage became a little. For particle size 0.125~0.250 mm fraction, the coal particles adhered to the drum surface increase with the increase of the voltage, and the scattering coal particles decrease. Compared with the raw coal, for 1.0~2.0 mm the particle size (Datong coal), the sulfur and ash content of the cleaned coal fell 25% and 10%, respectively. And, in case of Zongliangsan coal of Chongqing, the collection of refined coal amounted to 57.6 %, ash and sulfur content decreased 11 % and 30.4 %, respectively. These results suggested that the coal cleaning using static electricity could effectively clean the low-grade raw coal. By the way, for Taiheiyo coal, because there was a little sulfur content, an important point of this test is to reduce ash content. As the results of cleaning test, the ash content was reduced from 29% to 14%.

4.7 Experimental of the Bench Scale Coal-cleaning Equipment with Static Electricity

Three types of coal (≦ 0.125 mm, 0.125~0.5 mm and 0.5~2.0 mm) were cleaned by the dry coal-cleaning equipment in Nantong of Chongqing, the treating ability of which is 1 ton per hour. The experimental results were shown in Figure 5.

Compared with the raw coal, the sulfur content and ash of the cleaned coal decreased from 3.29% to 2.34% and from 29% to 20%, respectively. The calorific value increased from 5,870 kcal kg^{-1} to 6,660 kcal kg^{-1}. Furthermore, the ash wastes existed in 13.4%, which contained 48.6% ash and 8.45% sulfur. Its calorific value was only 4,260 kcal kg^{-1}. The collection efficiency for the refined coal amounted to 86%. It is considered that this machine has excellent coal-cleaning efficiency. Thus, the power consumption was only less than 1.0 kW. Compared with wet method, the cost the method for the dry coal-cleaning is lower.

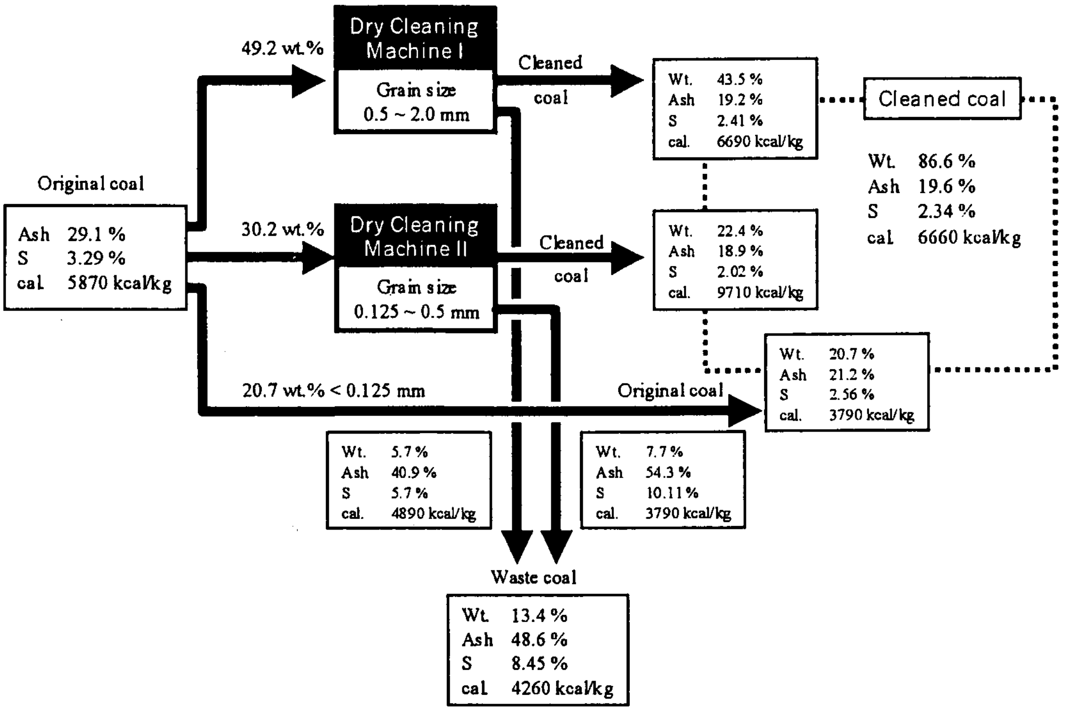

Figure 5. The evaluated results of bench static electricity coal-cleaning equipment.

4.8 Comparison on Several Types of Coal Cleaning Machine

The comparison on several types of coal-cleaning machine was shown in TABLE II. Compared with wet, the collection efficiencies of the refined coal in dry coal-cleaning machine were higher through there were lower desulfurization efficiencies and ash reduction rate. Especially, the dry method has not to consume any water resources and need lower energy consumption.

TABLE II. The comparison on several types of coal-cleaning machines.

Machine and method	Wet method	Small dry coal-cleaning	Improved dry coal-cleaning	Bench dry coal-cleaning
Experimental sites	China	Japn	Japan	China
Sample coal size (mm)	0.5~50	0.125~2	0.125~2	0.125~2
Water consumption (ton/ton-coal)	3	no	no	no
Power consumption (kw/ton-coal)	13~15	No data	0.9	Less than 1.0
Collection efficiency (%)	70	86	86.6	80
Desulfurazation efficiency (%)	59	29	28.9	31.6
Ash reduction rate	41	31	32.6	11.5
Change of heat capacity	+8.3	+13	+13.5	No data

5. Conclusions

Coal-biomass briquette, a new kind of artificial solid fuel produced by a mixture of coal, biomass, new desulfurizer under a high compression pressure, has been developed in this study. The combustion experiments show that coal-biomass briquette has a lower ignition temperature and a shorter burnout time comparing with normal coal briquette. The addition of limestone, scallop shell, calcium hydroxide, and an industrial waste in coal-biomass briquette can greatly decrease SO_2 emission. While the effective distinguishing features of coal-biomass briquette will be acknowledged by the local scientists, the concurrent technology transfer of coal-biomass briquetting technique to Chongqing of China will be achieved, which is one of the important purposes of this study project.

In this study, three types machines for dry coal cleaning with static electricity were developed. Compared with wet method, though the desulfurization efficiencies and ash reduction rate were a little lower, their water and power consumption were rather little. It is possible to improve efficiencies through elect suitable run condition. Also, in the conventional wet method, equal to or less than 0.5 mm coal is disposed of without election and the election efficiency of equal to or less than 3 mm is very bad, too. Therefore, the dry coal cleaning to apply to the coal with 2~ 3 mm size sufficiently has the possibility as the popular mining mechanization, and could be introduced to local-size production as a coal cleaning technology of the expected fine coal particles.

Reference

1) Qing-yue WANG, Kazuhiko SAKAMOTO, Toshihoko MARUYAMA, Tsuguo MIZOGUCHI, Shiro HATAKEYAMA, Ren-xue LUO and M KAMIDE, Development and Studies on Coal-biomass Briquetting Process as An Emission Control Technique for Precursors of Acidic Deposition in Chongqing, China, *The paper of 11th World Clean Air And Environment Congress*, Durban, South Africa, Vol.2,7C-4(1998.9)
2) Qing-Yue Wang, Guo-Qing Lu, Hee-Joon Kim, Toshihiko Maruyama, Kazuhiko Sakamoto and Shiro Hatakeyama: “Combustion Characteristics of Elliptical Coal-Biomass Briquette”, *Atmospheric Sciences and Applications to Air Quality 6th International Conference*, Beijing, China(1998.11)
3) Qing-Yue Wang, Guo-Qing Lu, Kazuhiko Sakamoto, Toshihiko Maruyama, Tsuguo Mizoguchi, Shiro Hatakeyama, Hee-Joon Kim and Xu-Hui Dong: “Practical Study on Coal-Biomass Briquette for Air Pollutant Emission Control in Chongqing, China”, *Atmospheric Sciences and Applications to Air Quality 6th International Conference*, Beijing, China(1998.11)
4) Qing-Yue Wang, Air pollution in China – the Present and the Future -, *Kankyougijutsu*, 27, 616~623 (1998) (in Japanese).
5) Qing-Yue Wang, Practical Use of Coal-biomass Briquette (Biocoal) Production Technique for Integrated Environmental Protection Strategy in China, *Kankyoukanri*, 35, (1999) (in Japanese).
6)