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A Study on the Thermal and Chemical Characteristics of Wasted Coal for the Development of Low Cost Fuel

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Abstract: The seawater involving diverse chemical elements was mixed with wasted coals to improve the quality. The thermal and chemical characteristics of these seawater-mixed coals were investigated and compared with those of original coals. The contents of MgO, Na_2O, and K_2O were increased by mixing seawater in wasted coals. The content of Na_2O in these coal samples was greatly increased due to the sodium, which was the main component of seawater. Thus, it was expected that fusion temperatures of these coal samples were decreased. Coal samples mixed with seawater showed that the rapid weight loss was started at the lower temperature than those of original coal samples. In these coal samples, the temperatures of maximum heat emission were lowered by average 61℃. Thus, it is suggested that some chemical constituents of the seawater act an important role on lowering the ignition temperature of wasted coal. By mixing seawater into wasted coals, the calorific values were increased. Especially, calorific values were greatly increased in the coal samples of lower quality as Baksan A and B with the improvement of 15~20%.

Keywords: Coal, Seawater, Calorific Value, Fuel

Introduction

In Korea, agriculture has changed to an energy intensive industry. To overcome a shortage of labor in agriculture, government has concentrated to the automatizing of agricultural facilities such as greenhouses and animal housings for a long period leading agriculture to the energy consuming industry. However, the petroleum being used during wintertime for heating most agricultural facilities is totally imported from other countries, because the energy resources are very limited in Korea. Furthermore, an energy problem has become more serious in agricultural industry with the increase of energy cost for heating agricultural facilities and processing of agricultural products. The rise of energy cost has induced the increase of the expense in farms for production and processing of agricultural products. Thus, there has been much interest in developing new fuels as alternative to petroleum.

The use of our enormous waste resources in efficient constitutes one of the major challenges of our time. Now with increasing generation of solid waste and decreasing space for landfill sites, waste-to-energy is emerging as a promising option for the future. Wasted materials can be used to meet a variety of energy needs, including generating electricity, heating homes, and providing process heat for industrial and agricultural facilities. Waste products include wood waste materials (e.g. sawdust, wood chips, etc), crop residues (e.g. rice straw, corn husks, wheat chaff, etc), mine waste (e.g. wasted coal) and municipal, animal and industrial wastes (e.g. plastics, sewage sludge, manure, etc). The net energy available from solid waste when it is combusted ranges from about 8 MJ/kg for green wood, to 20 MJ/kg for dry plant matter (1998, Demirbas) as compared with about 27 MJ/kg for coal (1998, Twidell). Co-firing method of solid waste with primary fuel (coal, natural gas, furnace oil) can be a low cost method by providing an end use for low value or negative value products (Battista Jr. et al., 2000; Sami et al., 2001). Some typical biomass fuels as waste products found in coal co-firing studies are: cattle manure (Frazzitta et al., 1999), sawdust and sewage sludge (Abbas et al., 1994), and wood chips (Sampson et al., 1991).

Coal is a complex polymer consisting primarily of carbon, hydrogen, oxygen, nitrogen, and sulfur. It is a compact, aged form of biomass containing combustibles, moisture, intrinsic mineral matter (originating from dissolved salts in water) and extrinsic ash (due to

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mixing with soil). Coal is the most potential energy source in Korea, because the coal of 0.75 billion ton has availability of mining in an estimated amount of coal deposits of 1.6 billion ton. However, the coal industry has continuously declined since 1980s. A lot of wasted coal of low quality, which was produced at the time of flourishing of coal industry has been left near the railroad station and coal-mining areas in Korea. This coal of low quality has less than calorific value of 4,000 kcal/kg. Thus, it cannot be made to the briquette for using as the solid fuel. The wasted coal can be obtained cheaply at an expense of transportation only. If the low cost fuel is developed by improving the quality of this coal, a lot of wasted coal can be used as an energy source for heating agricultural facilities during winter season and reduce the production cost of agricultural products.

Therefore, this study was carried out to investigate the characteristics of wasted coal with mixing seawater involving diverse chemical components for the development of low cost fuel. The thermal and chemical characteristics of seawater-mixed coals were compared with those of original coals.

Materials and Methods

Wasted coal samples were obtained at the mining areas of Dogae, Sabuk, and Baksan in Korea. Two samples were collected from each mining area, and these coal samples were named as Dogae A, Dogae B, Sabuk A, Sabuk B, Baksan A, and Baksan B, correspondingly. The thermal and chemical characteristics were investigated by examining wasted coals mixed with seawater obtained from East Sea in Korea, which were named as Dogae A (SW), Dogae B (SW), Sabuk A (SW), Sabuk B (SW), Baksan A (SW), and Baksan B (SW). The seawater of 0.1 ℓ was poured into the container filled with wasted coal of 1kg and stirred well. Then, this coal mixture was dried in the drier set at 60℃ for 24 hours and broken into small particles by hammer. Coal powders of the fine particles were obtained by passing original or seawater-mixed coals through the sieve of #40 mesh. These coal samples were used for the analyses of thermal and chemical characteristics.

Analysis for chemical constituents of coal ash was carried out by Xray Fluorescence Spectrometer (XRF) (Model Philips PW1480, Philips Analytical B. V., USA). In this analysis, coal sample was fused as glass beads with flux (lithium tetraborate) at 1,200℃ after combusted at 950℃ for 30 min. The thermal characteristics of coal samples were examined by thermal analysis system (Model DST2960, TA Instruments Co., USA), which is TGA-DSC (Thermogravimeteric Analyzer Differential Scanning Calorimeter) type. In this analysis, temperature was increased up to 1,300℃ at the rate of 20℃/min in the air environment with using coal sample of 20~30 mg. The calorific values of coal samples were also measured by oxygen bomb calorimeter (Model 1341, Parr Instrument Co., USA).

Results and Discussion

1. Chemical analysis

Table 1 shows the chemical constituents of coal ash analyzed by XRF. All of coal samples collected from Dogae, Sabuk, and Baksan were composed of the same constituents of inorganic substance, even though their quantities were different in weight percent. Main constituents of coal samples were SiO_2 and Al_2O_3, which were composed in the range of 29~62%. Also, the constituents of Fe_2O_3 and K_2O were in the range of 1~5%. It has known that alkali constituents such as Fe_2O_3, MgO, Na_2O, K_2O, etc have a role on lowering the fusion temperature of ash (Singler, 1981). In coal samples mixed with seawater, the content of MgO, Na_2O, and K_2O were increased. Especially, the content of Na_2O in these coal samples was greatly increased due to the sodium, which is the main component of seawater. Thus, it was expected that fusion temperatures of these coal samples were decreased. The content of SiO_2 was a little decreased in coal samples mixed with seawater.

2. Thermal analysis

The results of TGA-DSC analysis for coal samples are shown in figs. 1, 2, and 3. Differential scanning calorimeter (DSC) is to measure the heat flux of coal samples with temperature change. Thermogravimetric analysis (TGA) is to measure the weight change of coal sample according to temperature change. The weight losses of all coal samples were decreased slowly up to the temperature of about 100℃ because of moisture loss. It is considered that the peaks of heat emission and the rapid weight losses of coal samples being occurred in the range of 600~800℃ were due to oxidation of the organic substances. Coal

Table 1 Chemical constituents of coal ashes

(weight percent)

No	Sample	SiO_2	Fe_2O_3	Al_2O_3	TiO_2	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5
1	Dogae A	59.65	3.19	31.60	1.71	0.00	0.44	0.48	2.94	0.00	0.00
2	Dogae A (SW)	57.11	3.15	32.24	1.90	0.02	0.61	0.63	3.06	1.09	0.15
3	Dogae B	60.84	2.22	31.87	1.73	0.00	0.33	0.37	2.49	0.00	0.14
4	Sabuk A	50.94	4.69	34.57	2.02	0.07	1.45	0.87	5.09	0.02	0.25
5	Sabuk B	53.94	3.98	33.86	1.81	0.04	0.56	0.72	4.77	0.09	0.22
6	Sabuk B (SW)	52.23	4.25	33.82	1.88	0.04	0.66	0.81	4.99	1.09	0.21
7	Baksan A	61.34	3.24	29.56	1.28	0.00	0.52	0.58	3.47	0.00	0.00
8	Baksan A (SW)	60.12	3.15	29.68	1.24	0.05	0.64	0.64	3.50	0.89	0.11
9	Baksan B	61.17	1.41	31.86	1.39	0.02	0.21	0.48	3.26	0.10	0.07

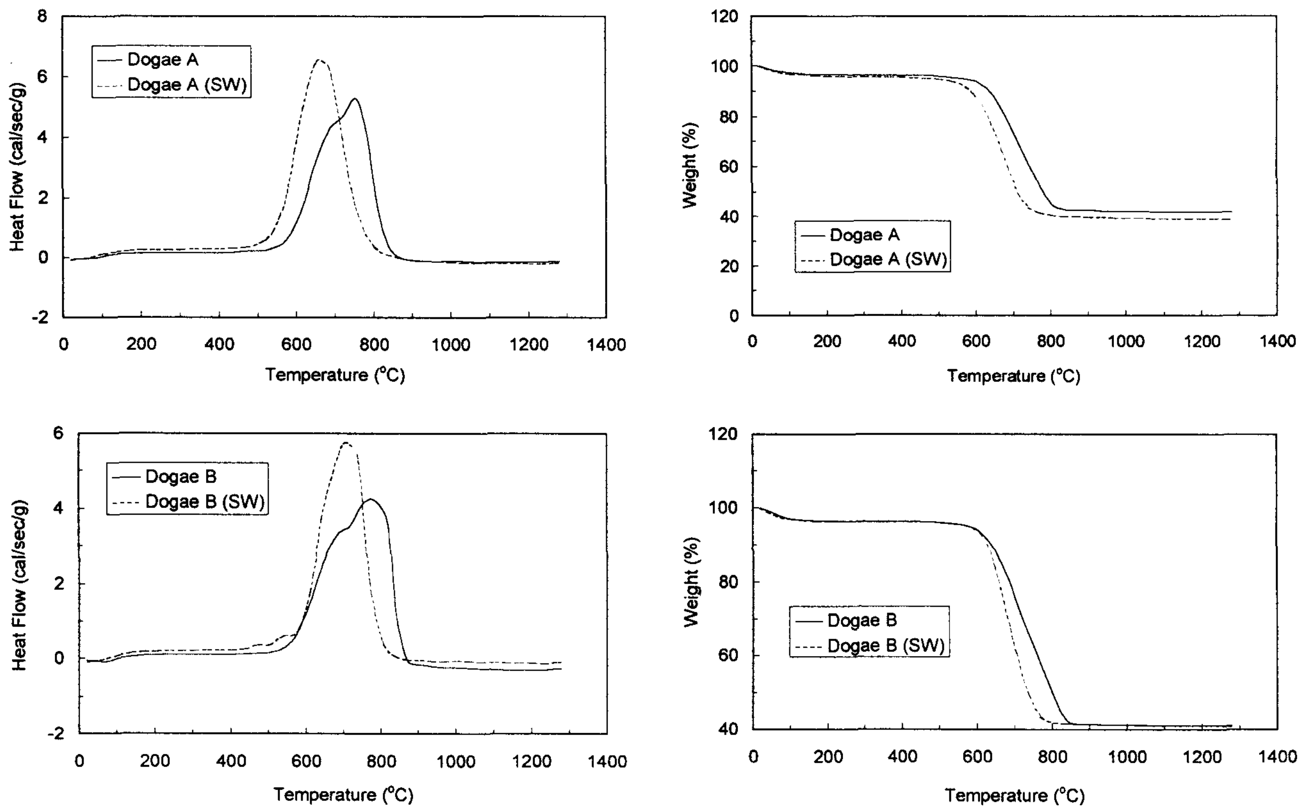

Fig. 1 TGA-DSC curves of Dogae coal samples.

samples mixed with seawater as Dogae A (SW), Dogae B (SW), Sabuck A (SW), Sabuk B (SW), Baksan A (SW), Baksan B (SW) showed that the weight losses were started at the lower temperature than original coal samples. Also, in these coal samples, the temperatures for maximum heat emission were lowered by average 61℃, while an amount of weight loss was not significantly different between original and seawater-mixed coal samples (table 2). It is known that various ions such as Na^{+}, K^{+}, Mg^{2+}, Ca^{2+}, Cl^{-}, SO_4^{2-}, HCO_3^{-}, etc are existed in the seawater. As coal is mixed with seawater including these ions, the decomposition of the

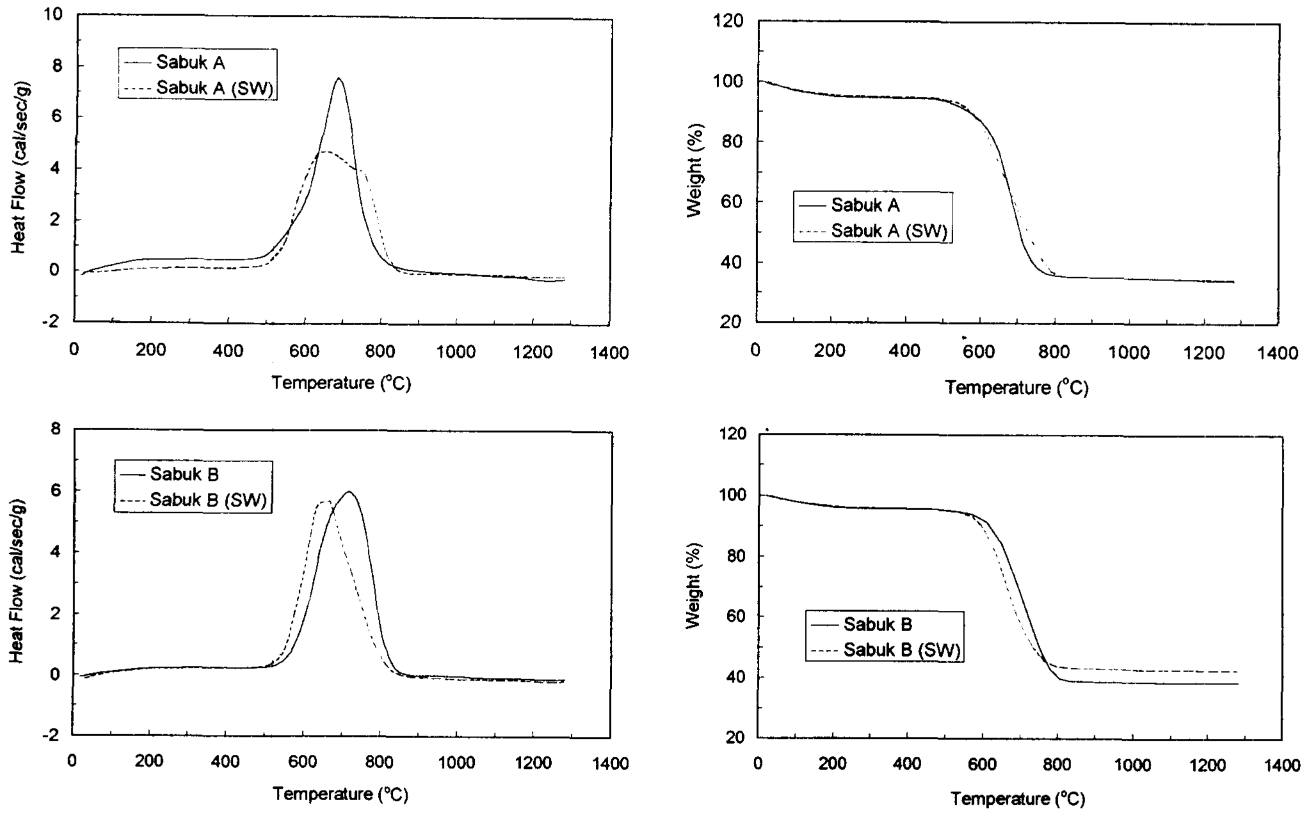

Fig. 2 TGA-DSC curves of Sabuk coal samples.

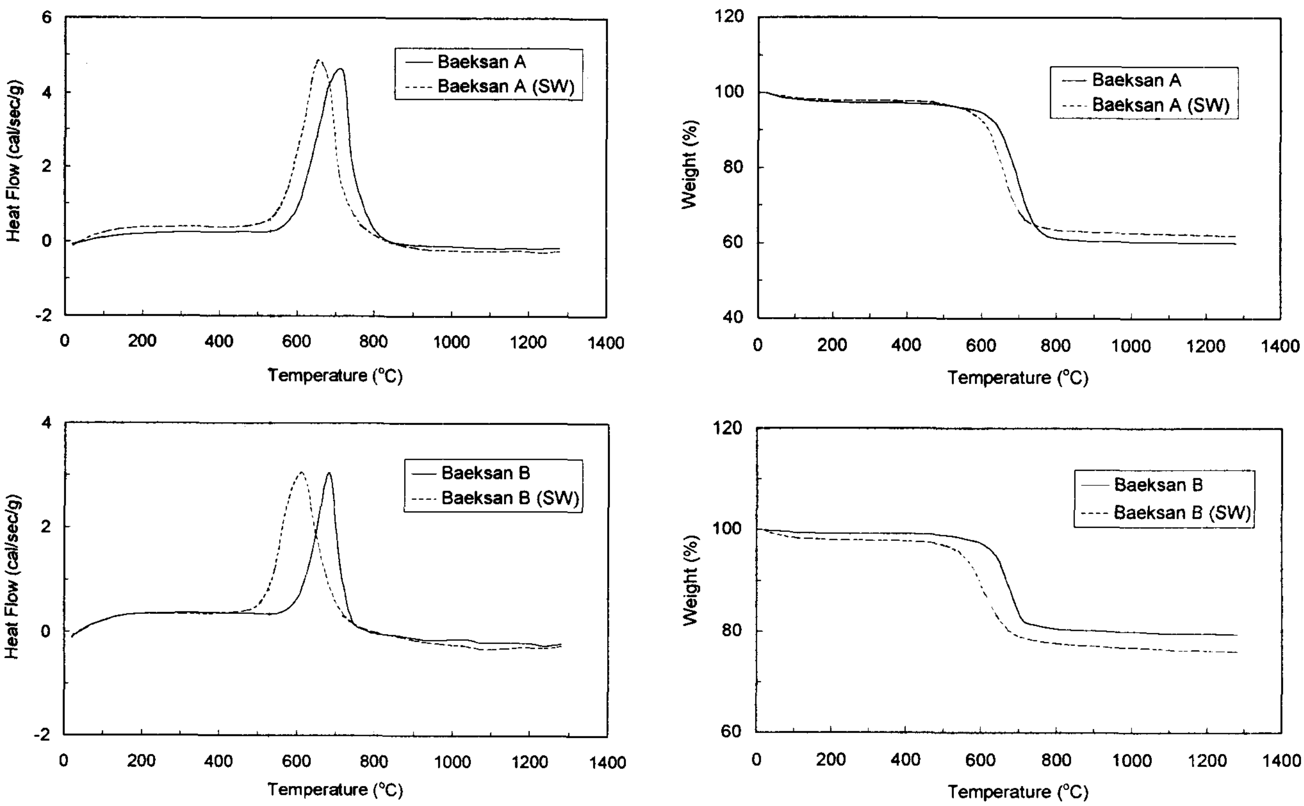

Fig. 3 TGA-DSC curves of Baksan coal samples.

Table 2 Weight losses and maximum emission temperatures of coal samples from TGA-DSC analysis

Sample	Weight loss (%)	Maximum emission temperature (℃)
Dogae A	58.13	753.2
Dogae A (SW)	60.89	666.6
Dogae B	58.97	777.2
Dogae B (SW)	59.02	739.5
Sabuk A	65.80	687.2
Sabuk A (SW)	65.38	657.2
Sabuk B	61.57	729.9
Sabuk B (SW)	57.31	654.2
Baksan A	39.96	710.5
Baksan A (SW)	37.93	660.4
Baksan B	20.56	684.6
Baksan B (SW)	23.86	600.7

Table 3 Calorific values of coal samples measured by oxygen bomb calorimeter

Sample	Calorific value (kcal/kg)	Sample	Calorific value (kcal/kg)
Dogae A	3,414	Sabuk B	3,302
Dogae A (SW)	3,633	Sabuk B (SW)	3,568
Dogae B	3,400	Baksan A	2,153
Dogae B (SW)	3,630	Baksan A (SW)	2,478
Sabuk A	3,806	Baksan B	928
Sabuk A (SW)	4,032	Baksan B (SW)	1,125

original organic compound may occur and produce various salts because of bonding structure of coal molecular may be easily disconnected. This reaction may minimize the molecular weight of coals and decrease the temperature for the maximum heat emission. Therefore, it was known that some constituents of the seawater play an important role in lowering the ignition temperature, which is the great problem of wasted coal.

Table 3 shows calorific values (higher heating values) which were averages of three replications for each coal sample. The calorific values of seawater-mixed coal samples were greater than those of original coals. With mixing seawater, calorific value was greatly increased in the coal samples as Baksan A and B, which showed the improvement of 15~20%. However, the increase of calorific values by mixing of seawater was only in the range of 5~8% for coal samples of Dogae and Sabuk, which have better quality than those of Baksan.

Conclusions

It is expected that fusion temperature might be decreased due to the increase of the content of MgO, Na_2O, and K_2O in coal samples mixed with seawater. In seawater-mixed coal samples, the temperatures for maximum heat emission were lowered by average 61 ℃. Coal samples mixed with seawater showed that the weight losses were started at the lower temperature than those of original coal samples. An amount of weight loss was not significantly different between original and seawater-mixed coal samples. It was known that some constituents of the seawater play an important role in lowering the ignition temperature with increasing calorific value of low quality coal. The calorific values of seawater-mixed coal samples were greater than those of original coals. With mixing seawater, calorific values were greatly increased in the coal samples of lower quality as Baksan A and B with the improvement of 15～20%.

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