Triboelectrostatic Separation of Fly Ash

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ABSTRACT

The dry triboelectrostatic separation of fly ash derived from both coal combustion and the combustion of coal mixed with 10 wt.% biomass were conducted. Two different types of triboelectrostatic separators - parallel plate and louvered plate separators - were used for this study. It is found that the quality of separation is dependent upon the nature of fly ash and the configuration of the separator utilized.

INTRODUCTION

The utilization of power-plant-derived fly ash has an impact on the cost of power production from coal. The usage has been hindered by recent shifts to low NO_x burners which can increase the carbon content of the ash above the specification for its use in Portland cement. The post-combustion beneficiations can generate valuable unburned organic product and inorganic fly ash products, and these two constituents can be collected and used as commercial products. The unburned organic fraction can be recycled back to the burner as fuel or used as catalyst, activated carbon, or catalysts support. The purified inorganic fraction can be utilized as cement additives. Improved beneficiation and utilization schemes for fly ash can transform it from a waste material, with associated disposal costs, to a valuable product.

Electrostatic beneficiation of fly ash to separate unburned carbon has been investigated widely as an alternate to the other post-combustion cleaning technologies[1-3]. During triboelectrification, organic and mineral particles are charged with opposite polarity and separated by using an electrostatic separator. On contact with metal (copper), the organic particles become positively charged, and the inorganic mineral particles become negatively charged. The charged particles are then passed through an electrostatic separator consisting of two conducting electrodes, across which a high voltage is applied. Organic (unburned carbon) particles are attracted to the negative plate, and minerals are attracted to the positive plate. The separated samples were collected and analyzed to determine separation efficiency.

The co-firing schemes of coal with biomass in coal-fired boilers have generated some interests recently due to the potential benefits of lowering the emissions of anthropogenic carbon dioxide and other greenhouse gases. The potential biomass material being studied in FETC's 500 lb/hr combustor included switch grass, hybrid willow and other carbonaceous material. However, the effects on separation of the fly ash derived from the combustion of coal mixed with biomass need further study.

Research at FETC over the last several years has developed dry electrostatic separation technology for the removal of mineral impurities from pulverized coal. These techniques have recently been applied to the separation of carbon from fly ash to yield an ash rich product that meets specifications for use in concrete application. The ability to efficiently extract high purity carbon or ash from coal fly ash is important in the development and application of cost-effective beneficiation technologies for the production of value-added products. In addition to a typical fly ash sample studied in the past, we also use samples of biomass fly ash to investigate the effects of separation associated with different feed sources.

EXPERIMENTAL

Triboelectrostatic research at FETC has focused on development of the totally pneumatic systems without mechanical charging devices. Two different types of separators - parallel plate and louvered plate separators - were used for this study. The details of these separators are described elsewhere [4]. In this work we used this parallel plate separator to evaluate a variety of feed fly ash so that their performance curves could be compared. In this application separations are done with the injector in five positions with respect to the splitter-centered on the splitter, displaced 0.635 or 1.27 cm toward the positive plate and displaced 0.635 or 1.27cm toward the negative plate (position right). The concentrated unburned carbon (attracted to the negative electrode) generated in these five runs, together with the feed, are then analyzed for carbon and ash content to yield a performance curve. These curves can be used to evaluate the potential of fly ash for separation and to compare the responses of fly ash from different sources.

The louvered plate separator is similar in construction to that of parallel plate. The major difference is in the separation zone. In the separation zone, it has louvered plates versus that of large plates in the parallel separator. The particles charging characteristic are dependent on the type of material used for construction of the tribocharger (copper and Teflon). The collected products from different sections of louvered plate, from the center, together with the feed, are then analyzed for carbon, ash, sulfur, and mineral content.

These experimental configurations were used to measure the dependence of the separation on two types of fly ashes. One is derived from the combustion of a Black Creek Pittsburgh seam coal (the carbon content of 7.74 wt.%). The other is obtained from the combustion of coal mixed with 10 wt.% switch grass (the carbon content is 4.84 wt.%).

RESULTS AND DISCUSSION

The quality of this triboelectrostatic separation process can be determined by measuring the cumulative recovery of ash on the products collected from the positive plate and unburned carbon content as a function of the position of the splitter in the parallel separator (Fig. 1). The yield of ash rich matter and unburned carbon content on the mineral rich side is presented as a percentage of the total amount of each component in the feed. Typical performance curves for coal fly ash versus different types of separators are shown in Fig. 1. The recovery of mineral rich matter in the feed on the positively charged side is nearly 77% for coal fly ash with the splitter located to the right 1.27 cm position. This product, containing 77% of the mineral matter, contains 7.19 % of the carbon compare that of 7.74 % in the feed which indicates the selectivity of this process. A slightly increase in the unburned carbon content to 7.52% is observed as the splitter is moved to the right 0.635 cm position; however, the ash recovery drops to around 68%. Further reducing the unburned carbon content to 6.7 % could be achieved by adjusting the splitter to the center position in the separation chamber. The ash recovery for this collected product is around 52%. The mineral rich product which contains 5.1 % of unburned carbon along with an ash recovery of 41% could be achieved by adjusting the position of the splitter to the left 0.635 cm position. Further decreasing the carbon content to 4% with an ash recovery of 22% could be obtained by repositioning the splitter to the left 1.27 cm position. This significant reducing of the unburned carbon content from 7.74% in the feed to 4% in the ash rich product is at the expense of the recovery of the mineral matter. Fig. 1 also illustrates the results obtained from the louvered plate separator with different type of material of construction for the tribocharger. A product with unburned carbon content of 4.3 % and 42% of ash recovery could be collected from the negatively side of a louvered plate separator with a copper tribocharger. Furthermore, a product with less than 3 wt.% of unburned carbon and 21% of ash recovery was achieved by collecting the products passing between both louvered plate via a Teflon tribocharger.

The louvered plate separator with the capability for multiple separated outputs was utilized to collect the possible fractionated ash components.   Initial visual observation on the separated products (Table 1) indicated that there are three distinguishable portions on the louvered plate. This suggests that fractionation affects the separated products. The different materials have different work functions and will take on different charges when in contact with the tribocharger. Therefore, the combination of external electric force, electron charge to mass ratio, and particle initial velocity will result in different trajectories for different particles. The lighter particles will be deposited on the upper portion of the louvered plate. The heavier particles will be collected on the lower portion of the louvered plate. Those particles that did not charge will pass through the center. The effects of different tribocharger material of construction (copper versus Teflon) on the separations was conducted. The charging phenomena may vary as the construction material of the tribocharger changes. The results shown in Table 1 indicate that the tribocharger material of construction affects the separation. With the copper tribocharger, 59% of the feed was charged and collected on the plates. In the case of Teflon tribocharger, the recovery increased to 79% of the feed. These results suggest that Teflon may be a more efficient charger than copper for fly ash separation. The deposition pattern of the collected material is also different for the two tribochargers studied. In the copper tribocharger case, the majority of the products is collected on the positive plate. However, in the case of the Teflon tribocharger, most of the products is deposited on the negative plate. Therefore, the contents and quantity of the collected products could be fine-tuned by adjusting the material of construction for tribochargers. A product with less than 3 wt.% carbon contents was generated by utilizing the Teflon charger. This product can be used for cement application without further purification.

Table 1. Triboelectrostatic separation of the coal fly ash via a louvered plate separator.

Sample	**Ash Recovery, %**	**Moisture %**	**Ash %**	**Carbon %**
Coal Ash, copper charger	100	0.94	91.32	7.74
Product collected in (+) plate	41.63	0.59	95.06	4.34

Product collected in (-) plate	17.79	1.18	90.28	8.53
Product collected in the bottom	40.56	1.17	88.20	10.63
Sample	**Ash Recovery, %**	**Moisture %**	**Ash %**	**Carbon %**
Coal Ash, Teflon charger	100	0.94	91.32	7.74
Product collected in (+) plate	20.19	0.83	92.20	6.97
Product collected in (-) plate	58.94	0.70	89.72	9.58
Product collected in the bottom	20.85	1.77	95.24	2.99

The dry triboelectrostatic separations of fly ash derived from both coal combustion and the combustion of coal mixed with 10 wt. % biomass were also performed. The triboelectrostatic separation of coal fly ash and 10 wt. % switch grass fly ash were conducted in the louvered plate with Teflon charger and the parallel plate separator with the splitter position in the center. The results of this study are tabulated in Table 2.

Table 2. Triboelectrostatic separation of coal and 10wt. % switch grass fly ash via parallel plate and louvered plate separators.

Parallel plate separator, splitter position, center	**Ash Recovery,%**	**Moisture %**	**Ash %**	**Carbon %**
Coal Ash, as received	100	0.79	91.74	7.47
Product collected in the (+) electrode	50.9	0.83	92.85	6.32
Product collected in the (-) electrode	43.76	1.30	87.18	11.52
10 wt.% switch grass fly ash, as received	100	1.04	94.12	4.84
Product collected in the (+) electrode	48.6	1.04	94.14	4.82
Product collected in the (-) electrode	42.08	1.20	93.31	5.49
Louvered plate with Teflon charger	**Ash Recovery,%**	**Moisture %**	**Ash %**	**Carbon %**
Coal Ash	100	0.79	91.74	7.47
Product collected in (+) plate	20.19	0.67	92.36	6.97
Product collected in (-) plate	58.94	0.84	89.58	9.58
Product collected in bottom	20.85	0.93	96.08	2.99
10% switch grass ash	100	1.04	94.12	4.84

Product collected in (+) plate	29.02	0.93	94.19	4.88
Product collected in (-) plate	57.15	0.93	94.70	4.37
Product collected in bottom	13.82	0.93	91.65	6.63

The results in Table 2 indicated that the simple parallel plate and louvered plate separators are able to provide some separation on coal fly ash. However, in the case of fly ash derived from combustion of coal mixed with 10 wt.% switch grass, neither the parallel nor louvered plate separators provide a quality separation. It is speculated that the poor separations were related to the physical and/or chemical nature of the coal and biomass fly ashes. Image analyses of the separated products and the parent ashes were conducted. The biomass derived fly ash contained a large portion of unburned grass. It is possible that the unburned grass might affect the flow patterns in the charging zone and discharge other charged particles, thus contributing to the poor quality separation. The other possible factor is the chemical nature of the biomass fly ash. Table 3 illustrates the details analyses of the fly ash samples.

Table 3. Samples analyses of switch grass, coal fly ash and biomass fly ash.

	Coal Ash	Switch Grass Feed	Biomass Ash
Ash	90.65	3.56	94.19
Al2O3	21.16	0.89	19.14
CaO	5.8	15.42	5.87
Fe2O3	13.17	0.64	10.81
K2O	1.4	6.07	3.37
MgO	1.06	3.81	1.67
NaO	1.06	1.1	0.99
SiO2	54.9	38.39	55.83
TiO2	1.09	0.06	0.99
P2O5	0.31	3.57	1.29

With the 10 wt.% mixed of the switch grass, the final biomass fly ash showed some distinguishable differences compared that with coal ash only. For example, the K_2O increased from 1.4% in coal ash to 3.37% in biomass ash. MgO also demonstrated some significantly increase from 1.06% in coal ash to 1.67% in biomass ash. It is speculated that the additional K_2O and/or MgO found in the biomass ash may change the concentration of electron vacancies on the fly ash surface[5]. As a result of this, the electric behavior varies, thus affects the separation.

CONCLUSIONS

Preliminary data on fly ash separation indicates that simple triboelectric separators utilized in this study are able to provide effective separation in producing an ash rich stream for concrete additive applications under some circumstances. The contents and quantity of the collected products in a louvered plate separator could be altered by utilizing different material of construction for tribocharger. The separators utilized in this study are not able to provide a quality separation for biomass fly ash. The poor separation of the biomass fly ash is probably due to the physical and/or chemical nature of the biomass fly ash.

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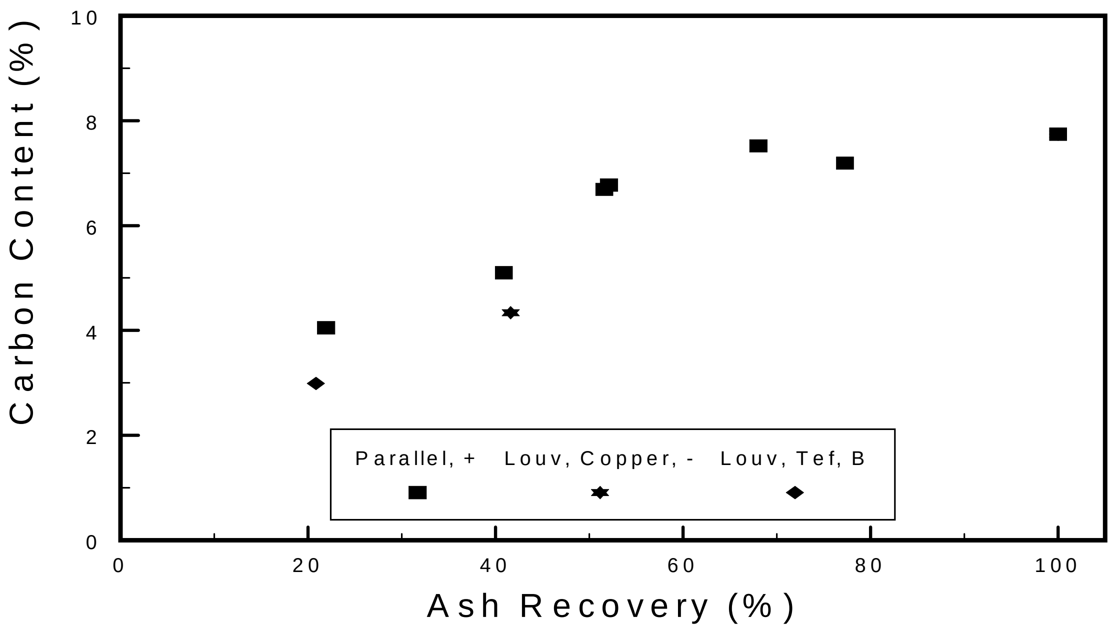

Fig. 1. Ash recovery vs. carbon content from different separators