Characteristics on the Electrostatic Separation and Tribocharging of Fly Ash Using a Ejector

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Abstract
The objective of this study was to investigate the possibility of the triboelectrostatic separation of unburned carbon from coal fly ash using a ejector-tribocharger with a SUS 304 for fly ash recycling. Experiments were carried out to study the effects of the rate of motive air, the particle density at ejector mixing section, the carbon content in fly ash fed, the relative humidity of atmospheric air inhaled, the flux temperature of mixture of air and particle, and the applied voltage between the two parallel electrodes on the charge-to-mass ratio and electrostatic separation efficiency. The charge-to-mass ratio and electrostatic separation tests using this separator performed by a fly ash sample with 7.5% carbon content. The test results of charge-to-mass ratio and separation efficiency found to be strongly affected by the change of the relative humidity of atmospheric suction air and the size distribution of fly ash than other parameters. Test results of triboelectrostatic separation efficiency indicated also that a fly ash of 7.5% LOI could be processed into 3.0% LOI product over a recovery of 80%.

1. Introduction
About 3.7million tons of coal fly ash were produced in Korea last year, of which only 32% were utilized with remaining 68% being disposed of as a waste. Due to the construction of new coal power plants, the fly ash production in Korea will increase for next 10 years and is expected to reach up to 5.7 millions tons in 2005. This rapid increase of the fly ash production cause serious concerns over fly ash disposal amid growing awareness of environmental issues and depletion of landfill sites. Naturally, utilization of coal fly ash is given a wide attention in recent years in Korea. It is well known that because of its spherical shape and pozzolanic properties, fly ash is a valuable and desirable additive to cement concrete. However, there have not been established a well-developed fly ash market in Korea, despite the advantage of using fly ash in concrete. A couple of main reasons can be related that quality of fly ash is not consistent enough such that stable supply is not guaranteed. However, key characteristics such as chemical constituents usually

193
satisfy the specifications of fly ash in Korea, except for unburned carbon contents. Presence of unburned carbon in fly ash imposes severe restrictions on the utilization of fly ash such as for cement/concrete mix. Content of unburned carbon in fly ash varies from plant to plant, and even daily at a plant, which makes it difficult to fulfill the requirement of consistent quality of fly ash for commercial use. The Korean Standard specifies that the loss on ignition (LOI) of fly ash for use in concrete be under 5% [KSL 5211 1992]. But concrete manufactures demand the LOI level of less than 3%. Therefore, it is essential to produce a consistent and uniform fly ash with less than 3.0% LOI by dry triboelectrostatic beneficiation. In the triboelectrostatic separation, particles of unburned carbon and fly ash can be imparted positive and negative surface charges, respectively, with a ejector tribocharger due to differences in the work function values of particles and the tribocharger material, and can be separated by passing them through an external electric field.

2. Materials and Methods
A fly ash sample was collected from the Poryung power plant owned by the Korea Electric Power Corporation. Fly ash sample was subjected to size fractionation. Fig. 1 shows the apparatus system for the triboelectrostatic separation. This system consists of three parts: control part (from number 1 to 7 in Fig. 1) of flow such as air rate, temperature, feed rate etc, ejector tribocharger part (number 8 in Fig. 1), and electroseparator part (number 11 in Fig. 1). The separator used in the study was batch type, had injet nozzle (A in Fig. 1: 15×0.5cm) parts with diverging type at inlet of electroseparator. The standard method for measuring charge is a Faraday cage system coupled to a suitable monitoring circuit (Keithly 617 HIQ, electrometer). Fig. 2 shows a schematic diagram of a our Faraday cage system. Faraday cage system was substituted for the electroseparator as shown number 11 in Fig. 1. As seen Fig. 2, the charged particle at ejector tribocharger introduced into the Faraday cage through the cyclone collector with insulator (acryl) material. All procedure for the experiments has been described elsewhere [Taylor, D. M. et. al., 1994].

3. Results and Discussions
Experiments were conducted at seven different air rates of 132, 165, 207, 248, 286, 326 and 367 ℓ/min. These air rates to ejector were achieved by controlling the air flow rate using the pressure regulator as shown in Fig. 1. The fly ash samples revealed charge accumulation with subsequent contacts and a net charge in the $1 \times 10^9$ C/g range in Fig. 3. In general, it has been that the resultant charge increases with increasing the air rate in ejector. Fig. 3 shows also the effect of the relative humidity of suction air. The maximum charge-to-mass ratio of fly ash with suction air at relative humidities of less than 30% showed at air rate of 326 ℓ/min,
and it at relative humidities of suction air of more than 40% showed at air rate of 367 l/min in range of this experiment. It can be seen that the total net charge is significantly reduced by increasing the relative humidity of suction air. Gradient of charge-to-mass ratio of fly ash at relative humidity of less than 30% below air rate of 326 l/min becomes larger than that of more than 40%. This phenomenon is ascribed to the change of surface properties and the increase of electrical conductivity by the adsorption of moisture at surface of fly ash. However, selectively charging each of the unburned carbon and fly ash effectively to separate the unburned carbon from fly ash is more significant than the total net charge of fly ashes. Once the fly ashes and unburned carbons become selectively charged into negative fly ash and positive unburned carbon with large magnitude, a electroseparation can be effectively achieved in the electric field. In order to investigate whether fly ashes and unburned carbon become selectively charged or not, separation efficiency tests of charged particles at ejector tribocharger were performed by a batch type of parallel electroseparator in Fig. 1. Fig. 4 shows the recovery of and LOI in fly ashes of the air rate at relative humidities of 30 and 60%. Recovery of fly ash can be defined as the percentage of recovered fly ash by feeding fly ash. As seen in Fig. 4, when air rate of 326 l/min at relative humidity of suction air of 30% was, maximum recovery of fly ash and minimum LOI in fly ash have. When air rate is largely increased into more than 326 l/min, due to the shortening of time of separating the fly ash and unburned carbon between the electrode plates or the driving force by compressor becomes larger than the electrostatic force of attracting the charged particles. Recovery of fly ash deposited on the positive electrode at relative humidity of suction air of 30% is also not proportional to LOI in fly ash recovered while recovery of fly ash at relative humidity of suction air of 60% depends on the LOI of fly ash recovered. That is, in case of relative humidity of less than 30%, the higher the air rate was, the higher the efficiency of selectively charging each of fly ash and unburned carbon was. Test results of triboelectroseparation efficiency indicated also that a fly ash of 7.5% LOI could be processed into 3.0% LOI product over a recovery of 70%. Fig. 5 shows the relation of the recovery of and LOI in fly ash layers deposited on the positive and negative electrodes at air rates of 326 l/min and electric field of 1.0 kV/cm. Most of the fly ashes were deposited in the range of 0~80cm distances. The fine ashes of lean carbon content are deposited on 0~60cm at upper positive electrodes while coarse ashes of high carbon content are deposited on the lower negative electrode of 60~80cm. Coarse fly ashes with containing 32.3% LOI are also collected at the bag filter. Fig. 6 shows the charge-to-mass ratio for the coarse, middle and fine fly ashes at the air rate of 326 l/min, the relative humidity of suction air with less than 30%.
References

KSL, "Fly Ash Standard", No. 5211, 1922

Fig. 1. Experimental system for the fly ash beneficiation
Fig. 2. Schematic diagram of a Faraday cage system

Fig. 3. Effect of the air rate on the charge-to-mass ratio of fly ashes
Fig. 4. Recovery and LOI of fly ash products obtained at various air rates.
(−): recovery, (··): LOI

Fig. 5. Recovery and LOI of fly ash of position deposited on the positive and negative electrodes. (−): recovery, (··): LOI
Fig. 6. Effect of size distribution for the charge-to-mass ratio of fly ash at various air rates