Assessment of Dielectric Characteristics of Fly Ash Ingredients Separated by Triboelectric Process

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Abstract

This paper presents dielectric properties of fly ash constituent combusted from coal. A novel dry beneficiation technique for Indian and imported flyash was adopted using a triboelectric separator unit with suitable design modifications for improved performance. The tribo separated fly ash samples were characterized for composition and electrical characteristics such as dielectric dissipation factor, dielectric constant and volume resistivity. The dielectric dissipation factor and permittivity of the imported flyash was much higher than that of the Indian origin. Volume resistivity of Indian flyash was much higher than that of the imported for raw, positively and negatively charged samples. The negatively charged Indian flyash samples showed lower power losses, higher dielectric constant and higher volume resistivity in comparison with those of the positively charged imported samples free from carbon species. Thus, the negatively charged fly ash samples of Indian origin possessed good dielectric properties.

Keywords: *Dielectric, Fly ash, Triboelectric Process, Coal*

1.0 Introduction

Fly ash produced from firing of coal poses serious environmental and health hazards since its disposal is difficult for thermal power stations and industries. The fly ash can be subjected to dry beneficiation involving novel triboelectric process [1] in which carbon and other minerals are separated. Some of the fly ash particles have higher affinity towards charge carrier electrons and become negatively charged, whereas lower affinity ones lose electrons and get positively charged. The coal beneficiation of triboelectric separator studied by Haifeng et al [2] provides useful information on treating pulverized coal in power plants and control the pollution rate by separating the impurities, especially unburnt carbon from coal before it is fed to furnace. Open literature

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indicates that lower level of lime fly ash is introduced as cementation component [3].

Tao et al [4] reported beneficial effect of tribo electrostatic separator of the fly ash samples on the yield due to the application of a strong electric field of about 45kV. Ling et al [5], studied influence of plate voltage on the separation of fly ash constituents using rotary tribo electrostatic separator and the resultant product obtained after separation was compared with those of the results obtained through numerical simulation. The maximum quantity of separation was obtained at plate voltage ranging from 24 kV to 26 kV, in both the cases [5]. Charlotte et al [6] investigated the unburnt coal ash separated from coal ash using dry beneficiation method. The authors implemented pre graphitization process to replace natural graphite to obtain carbon rich fraction during electrostatic separation, thus optimizing the role of electrostatic separation for better yield and effective separation.

The dry beneficiation of various types of fly ash samples has been carried out by choosing the input parameters for tribo separation such as electric field, nature of fly ash samples to be separated. Also the particle interactions and charging effect during carbon ash beneficiations using pneumatic triboelectric separation [7] has been reported. But, the electrical characterization of fly ash involving tribo electrically separated constituents has not been reported yet. Hence, the present work focuses on tribo separation of fly ash particles sourced from Indian thermal plant along with imported fly ash. Both the samples were assessed for their composition and electrical parameters such as dielectric dissipation factor, dielectric constant and volume resistivity.

2.0 Experimental Details

A laboratory scale triboelectric separator was suitably designed and modified for fly ash beneficiation as shown in Fig. 1. The fly ash samples of about 500 g, oven dried and sieved to particle size of 212µm were passed through a copper tribo charger tube/loop using compressed air as the carrier gas at a rate of 15 m/s. The tribo charged fly ash particles were then transported to a parallel plate electric field chamber at field strength of 200 kV/m. The applied voltage between the two electrodes plates was 25 kV. Thereafter the fly ash samples were separated based on the concept that the positively charged particles get attracted towards the cathode plate and negatively charged particles get attracted to anode plate. Then the particles were collected in two bins placed below the electrode plates. The fly ash samples were molded to solid circular discs and were to subjected oven drying and dielectric measurements.

The chemical composition was determined using Panalytical XRF spectrometer. The LOI of fly ash samples was measured by proximate analysis using Leco analyzer. A standard three terminal electrode system having high voltage electrode, low voltage electrode and guard was employed in a shearing bridge for measurement of dielectric dissipation factor (dielectric losses). The dielectric constant (permittivity) measurements were carried out using LCR meter (involving parallel plate concept). The resistivity meter was used for measuring volume resistivity at a voltage of 500V for test duration of one minute.

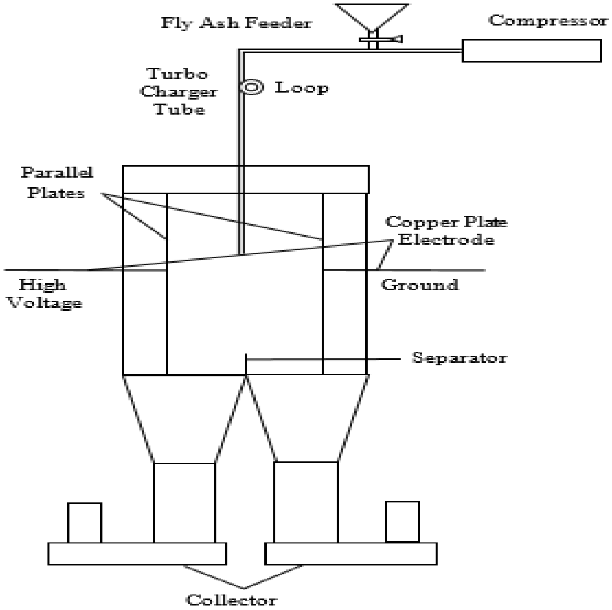

Fig. 1. Schematic representation of Triboelectric Separator Unit

3.0 Results and discussion

3.1 Composition analysis

Table 1 gives the elemental composition of Indian Origin Fly ash (INDFA) and imported fly ash (IMPFA) samples which included silica, alumina, ferrous oxide, calcium oxide and LOI. The results showed that INDFA possessed the silica ingredient double times than that of IMPFA. The alumina content was almost same in both the cases of fly ash. The LOI content of INDFA was less than one wt.% and makes it suitable for applications such as in concrete, which meets the requirements as defined in EN450 specifications [8, 9].

Table 1. Composition of raw fly ash samples

Sl. No.	Chemical Composition	Raw Composition Weight (%)	
		INDFA	IMPFA
1	Silica	50.21	38.37
2	Alumina	27.13	24.28
3	Ferrous Oxide	8.21	13.42
4	Calcium Oxide	2.76	13.29
5	LOI	0.97	10.91

3.2 Dielectric Dissipation Factor

The dielectric dissipation factor measurement of the raw and separated samples was carried out as per ASTM Standard [10] and the results are shown in Fig. 2. The carbon rich ingredients of fly ash exhibit higher dielectric losses in all the types of samples studied. It was observed that INDFA showed relatively lower dielectric losses than that of IMPFA for both the raw and separated samples. The dielectric dissipation factor increased considerably by manifolds in the case of IMPFA when compared to that of INDFA samples.

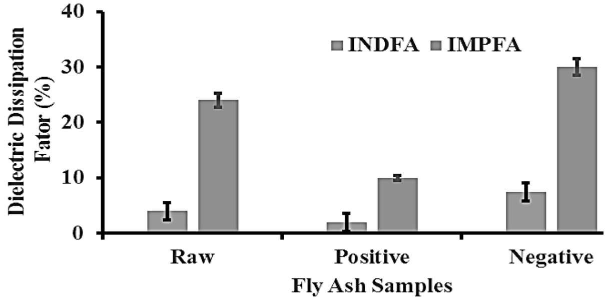

Fig. 2 Dielectric dissipation factor of fly ash samples.

The dielectric dissipation factor of INDFA for the raw, positively and negatively collected plates were 6, 5 and 4 times respectively lower than that of IMPFA. Higher the dielectric dissipation factor, higher is the power loss. Hence, INDFA exhibited better dielectric dissipation factor characteristics when compared to those of IMPFA. The dissipation factors of separated constituents of INDFA and IMPFA were low when compared to their corresponding raw samples. The reason for these trends was due to the presence of silica and LOI in the samples after separation.

3.3 Dielectric Constant

The dielectric constant (permittivity) test of the samples was carried out as per ASTM Standard [11] and the results are shown in Fig. 3. While, the INDFA samples exhibited moderate values, IMPFA samples were on the higher side before and after separation. The permittivity of INDFA for the raw, positively and negatively collected plates was 3, 2.5 and 2.3 times respectively lower than those of IMPFA. Since the permittivity obtained was of the order of about 10^{13}, the fly ash samples are best suitable for capacitance application with higher dielectric constant [12].

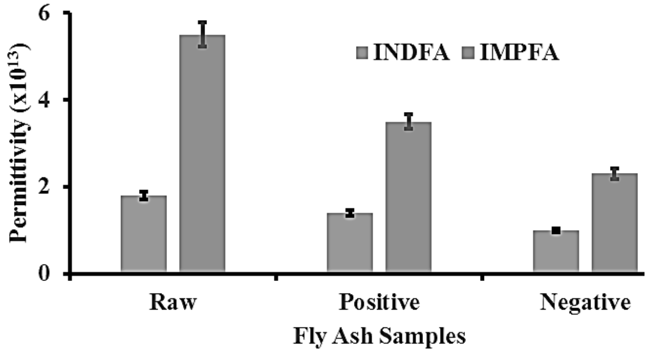

Fig. 3. Dielectric Constant of Fly Ash Samples.

3.4 Volume Resistivity

The volume resistivity of the samples was measured as per ASTM standard [13] and the results are as shown in Fig. 4. INDFA showed higher resistivity when compared to that of IMPFA samples.

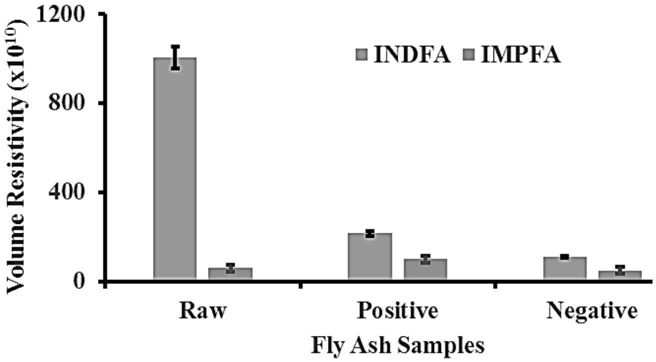

Fig. 4. Volume Resistivity of Fly Ash Samples.

The tribo-electrically separated fly ash samples were rich in carbon and other minerals and possessed similar characteristics. The decrease in resistivity of IMPFA may be due to clustering of ions occupying different positions which effectively lowered the concentration of stable bonds. The IMPFA sample, after the triboelectric separation showed a decrease in resistivity for the carbon rich product by the order of 10^3, while the mineral rich product exhibit an increase in resistivity by an order of 10^5. Although IMPFA had higher dielectric constant than that of Indian origin sample, it showed lower resistivity characteristics. On the other hand, the INDFA showed lower dielectric constant and higher volume resistivity, which can be attributed to the difference in intrinsic molecular bonds at the original source itself. In view of higher resistivity values obtained, the INDFA samples find application in insulating materials. Hence, INDFA samples can be employed for resistivity based sensor applications.

Conclusions

The present project focused on assessment of dielectric dissipation factor, dielectric constant and volume resistivity for INDFA raw, positively and negatively charged samples and IMPFA. A triboelectric separator unit was developed in house based on the modified design. The triboelectric beneficiation process yielded useful carbon and mineral rich products at the positive and negative electrodes from fly ash. The dielectric dissipation factor of IMPFA was much higher when compared to INDFA. The permittivity of IMPFA was slightly higher compared to that of INDFA. The volume resistivity of INDFA was much higher when compared to IMPFA for raw, positively and negatively charged samples. Further, the negatively charged INDFA samples show lower power losses, higher dielectric constant and higher volume resistivity compared to positively charged INDFA samples with free from carbon species. Thus, the negatively charged fly ash samples of Indian origin possessed good dielectric properties useful in the dielectric material development application.

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