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Classification of Ultra Fine Particles from Fly Ash

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Abstract

The annual generation of coal combustion residue in the country is 110 MT. The generation of coal combustion residue is expected to increase with ever increasing demand for power. Management of this solid waste has been a great concern to the nation. Most of the reports on utilization of coal combustion residue are limited to direct usage of the material or selective collection from ESP fields in the thermal power plants. In this connection several efforts are being made in the country to enhance its application as a replacement to cement, soil modifier, roads and embankments etc. Very little or no research attempts are made in understanding the appropriate components which results in beneficial properties and value added products. Fly ash in very fine size range exhibits spherical morphological characteristics and thus acts as good fillers in rubber and polymer compounds. However, recovery of this size material from the bulk is yet a challenge in the process industry as the material forms clusters at very fine sizes. The present study is an attempt to beneficiate fly ash to obtain material with an average particle size around 5 microns. A cyclone separator, which employs very high g forces for separation of particles is employed for achieving the separation. At this high g* forces, the declustering of particles is observed. This technique has generated product with an average particle size (d_{50}) between 4 to 8 microns. The results obtained at different test runs are discussed.*

INTRODUCTION

Fly ash is a fine particulate matter resulting from burning of fossil fuels in thermal power stations. Here the coal is ground to fineness and is fired in the boiler along with air. The combustible portions burnout within 3 to 5 seconds leaving the inert material as more or less molten spherical beads. These molten beads of ash forming material pass out of the furnace with the help of combustion gases forming solid beads as they progress further heights in the boiler. A small portion of unburnt carbon particles also report along with the ash particles. The ash particles are collected from the flue gas by electrostatic precipitators (ESP) and finally the gases are allowed to enter the atmosphere. The solid particles trapped in the ESPs are called flyash. Some portion of molten ash particles caught on the boiler tubes form slag or clinker and fall to the boiler bottom in the form of large pieces. The clinker is quenched and crushed to suitable size for slurry transport and the resulting product is called bottom ash. The flyash is either collected in dry form in the hoppers beneath the ESPs or discharged into ash dykes in slurry form by mixing with water. Every year huge quantities of flyash are being generated from various thermal power stations and their utilisation/disposal is of great concern to nation.

In India nearly 75% of the total installed power generation is coal-based. Around 230-250 million MT coal is being used every year. The amount of fly ash generated from 69 thermal power stations on 1998 was estimated to be of the order of 60MT. The estimate was updated to 90MT from 82 thermal power plants, having aggregate capacity of 60,000 MW in the year 2006. The current estimate of the amount of fly ash generated is of the order of 100MT per year, which is expected to go up every year, with increase in production of electricity from coal based thermal power plants (Mullick, 2005).

Though fly ash is considered a waste product of thermal plant, it has a potential to be a resource material in several industrial sectors. In recent years, there has been increasing interest in the processing of fly ashes to improve ash quality and consistency, and in the manufacture of high value secondary products. The potential application of fly ash is for making concrete products like building tiles, bricks, pozzolanic lime mortars/plasters, Portland pozzolanic cement, road construction etc. Other than concrete products flyash can be used as filler in paints, pigments and rubber industries based on certain physical and chemical properties. Reports have indicated that the characteristics of fly ash are close to a number of commercial fillers, however the particle size and brightness of flyash are still less desirable than those of commercial fillers (Plowman et. al., 1984, Jablonshi et.al., 1987, Huang et.al., 1995). The commonly used minerals as plastic fillers are calcium carbonate, kaolin, talc etc. Further it has been reported that clean ash with a maximum particle size of 5 microns can substitute the commercial filler requirement (Huang et. al., 2003).

Reports have been indicated that the ultra fine fraction in fly ash has added applications in the area of rubber, polymer and paints (Kruger et. al., 1999). The research reports indicted that particles with average size around 5μm in fly ash could have application as replacement for mineral fillers like calcite for obtaining better properties of materials. However, a separation methodology for receiving such fine particles in not revealed. Separation of pozzolonic material from lignitic Fly ash of Tuncbilek power station, Turkey was reported by (Orhan Ozdemir et. al., 2001). Reports also indicate different methodologies (passivation vs removal, combustion vs separation, wet vs dry methods of processing, air classification vs vibratory vs electrostatic separation vs screening), which suit for processing any specific kind of flyash material (Coates, M.E. and Afonso, R.F. (http://www.netl.doe.gov/publications/proceedings/00/ubc00/COATES1.PDF)).

Most of the reports pertaining to the utilization of fly ash in the Indian context are limited to direct usage of the material from selective fields in the thermal power plants. Reports to improve the quality of fly ash for enhancing certain properties like flyash reactivity, incremental benefits after processing fly ash etc. are not yet available. The utilization of coal combustion residue (CCR) in India is limited to 25 to 30%, indicating potential for research for widening the utilization in different new areas. Thus, in the present paper attempts made to recover ultra fine particles from fly ash, which can have applications in wide variety of industries.

EXPERIMENTAL

The test rig (Figure 1) used for carrying out the experimental work consists of a feed slurry tank of 200 liters capacity mounted on a stable platform. The bottom of the feed tank was connected to a centrifugal pump driven by a 3-phase, 5.5 kW motor. The outlet of the pump was connected to the feed inlet of a 76mm hydrocyclone. A by-pass pipe with a control valve was connected to the pump outlet line to maintain the required pressure drop inside the cyclone. A diaphragm type pressure gauge was fitted near the feed inlet to indicate the pressure drop. The hydrocyclone was positioned vertically above the slurry tank. For carrying out experiments slurry sample with measured amounts of fly ash and water were mixed in the feed tank to achieve a solids consistency of 10% by weight in the feed pulp. The slurry was pumped into the cyclone at desired feed pressure and at different spigot openings. Timed samples of overflow and underflow products were collected separately. The slurry samples were filtered and dried. Representative samples were analyzed for size distribution using Malvern lazer particle size analyzer. From the test results obtained on the weight distribution and particle size, distribution points of different size materials into the overflow product were generated. Distribution points were plotted against the respective sizes and cut size of the cyclone d50 values were generated at each experimental condition.

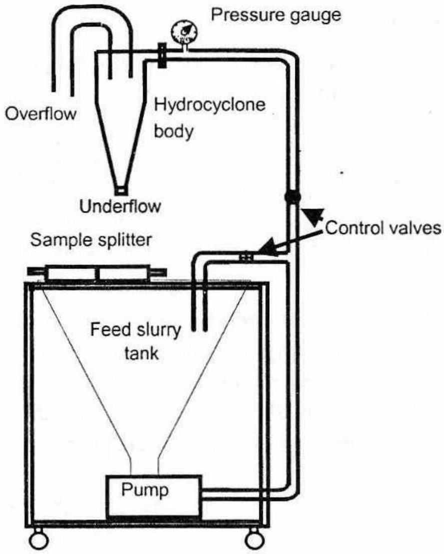

Fig. 1: Hydrocyclone Experiment Test Rig

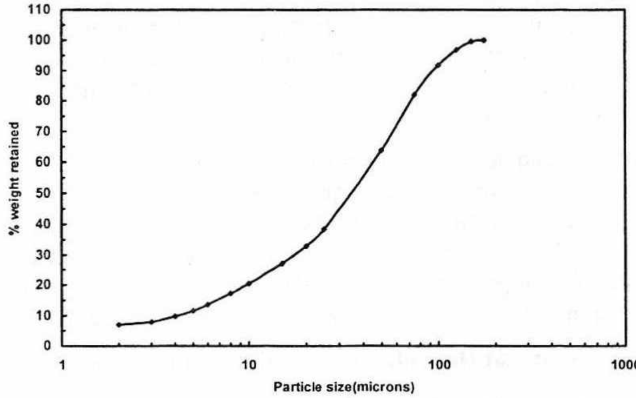

Fig. 2: Size Distribution of Flyash Feed

RESULTS AND DISCUSSION

The size analysis data of the feed sample is presented in the Figure 2. It can be observed from the figure that the average particle size (d_{50}) feed sample is around 35microns. Most of the sample is below the 100 microns. About 60% of the material is at a size below 50 microns and fines below 5microns in the feed are around 15%.

The results obtained in terms of solids throughput (capacity), solids split (percentage report to overflow) and cyclone cut size at different test runs are also presented in Table 1. It can be observed from the table that the solids split into the overflow product of hydrocyclone is varying between 8.4% at higher feed pressure and higher spigot opening to 30.0% at lower feed pressure and lower spigot opening. Similarly the cyclone cut size d_{50} is found varying between 28 microns to 8.5 microns at 8psi and 25microns to 7microns at 12psi. The effects of spigot opening and feed inlet pressure on throughput, solids split, and cyclone cut size (d_{50}) are discussed in the following sections.

Table 1: Experimental Conditions and Test Results

Exp. No.	Pressure (Psi)	VF D (mm)	SP D (mm)	% Solids Split (OF)	Cut Size (d_{50}) microns	Solids Throughput (tph)
1.	8	25	10	30.0	28.0	0.44
2.	8	25	15	21.3	18.0	0.45
3.	8	25	20	14.1	8.5	0.46
4.	8	25	25	10.0	---	0.49
5.	12	25	10	27.8	25.0	0.53
6.	12	25	15	20.1	17.0	0.55
7.	12	25	20	13.3	7.0	0.57
8.	12	25	25	8.4	---	0.60

*VFD – Vortex finder diameter

*SPD – Spigot diameter

Effect of Spigot Diameter and Feed Pressure on Solids throughput

It can be observed from the Table1 that as the spigot diameter increases the solids throughput increases. For instance an increase in spigot diameter from 10mm to 25mm at a feed pressure of 8psi has increased the throughput from 0.44tph to 0.49tph (Exp. no.1 and Exp. no. 4). This increase in the solids throughput is due to the reduced restriction for the material flow through the cyclone at higher spigot openings. Similar observation can be made at feed pressure of 12 psi. It can also be observed from the table that the influence of spigot opening is pronounced at higher feed pressure. An increase in the solids flow rate with an increase in the vortex finder diameter could be due to the increase in the area of passage for solids flow.

Further it can be observed from the table that at all the combinations of spigot openings, an increase in the feed pressure, increases the solids throughput. For example, at 10mm spigot opening an increase in feed pressure from 8psi to 12psi (Exp. no.1 and Exp. no. 5) has increased the solids throughput from 0.44 to 0.53tph. Similar effect on changes in feed pressure can be made at 15mm, 20mm and 25mm spigot openings. It may also be observed that between the spigot opening and feed pressure, variation in feed pressure influences the solids throughput more.

Effect of Spigot Diameter and Feed Pressure on Solids Split

It can be observed from the Table 1, that keeping the feed pressure constant at 8psi, an increase in the spigot diameter from 10mm to 25mm decreases the percent solids split into the overflow from 30.0% to 10.0% (Exp. no.1and Exp. no.4). Similarly at a feed pressure of 12 psi an increase in the spigot diameter from 10mm to 25mm has decreased the percent solids into overflow from 27.85% to 8.42% (Exp.no.5 and Exp.no.8). By increasing the spigot opening, the passage for the flow of material into the underflow increases. This in turn reduces the split into the overflow at higher spigot opening.

The effect of feed pressure on solids split is presented in Table 1. It can be observed from the table that there is a decrease in the solids split into the overflow for an increase in the feed pressure. For example at 10mm spigot opening, an increase in the feed pressure from 8psi to 12psi has decreased the overflow split from 30.0% to 27.8% (Exp. no.1 and Exp. no. 5). Similarly there is decrease in the split from 10.0% to 8.4% (Exp. no. 4 and Exp. no. 8) with an increase in the pressure from 8psi to 12psi at 25mm spigot opening. This decrease in the solids percent into the overflow is due to higher centrifugal forces developed in the cyclone at high pressures, due to which more amount of finer size solid particles report along with the coarser fractions into the underflow.

Effect of Spigot Diameter and Feed Pressure on Cut Size

The effect of spigot diameter on cut size at 8psi feed pressure is presented in Figure 3. It can be observed from figure that an increase in the spigot diameter decreases the cut size. For instance at 8psi feed inlet pressure, an increase in spigot diameter from 10mm to 25mm ha decreased the cut size from 28 microns to 7.5 microns. This is because as the spigot diameter increases the area of passage for relatively finer fractions for reporting into the underflow along with coarser material. Only the finest fraction will have chances to repot into the overflow. Similar observation on spigot openings can be made at higher pressure i.e. at 12psi from Figure 4. It can be observed from the figure that at 10mm spigot diameter the cut size is around 25microns, at 15mm spigot diameter cut size is around 17microns and at 25mm spigot diameter cut size is around 7microns.

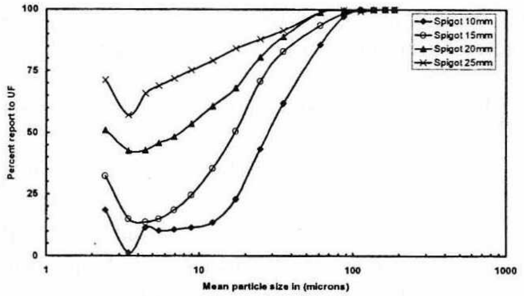

Fig. 3: Effect of Spigot Diameter on Cut Size (8psi)

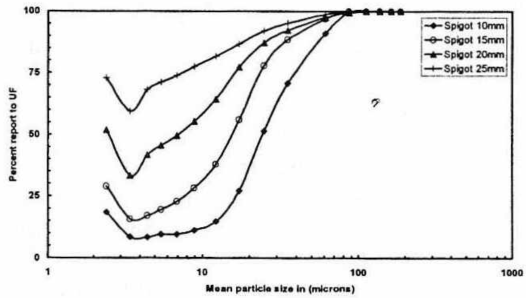

Fig. 4: Effect of Spigot Diameter on Cut Size (12psi)

Further the effect of feed pressure on the cut size is presented in Figures 5 and 6. The figures indicate that an increase in the feed pressure marginally decreases the cut size (d_{50}). For example, an increase in pressure from 8psi to 12psi at constant spigot diameter of 10mm has decreased the cut size from 29microns to 25microns. Further at a constant spigot diameter of 20mm, an increase in feed pressure from 8psi to 12psi has further decreased the cut size from 7.8 microns to 7microns. This decrease in the cut size can be explained due to the higher centrifugal forces on particles at higher feed pressures relatively finer particles reach the cyclone walls for being discharged to the underflow. Among the spigot opening and feed inlet pressure, the spigot opening influences the cyclone cut size more.

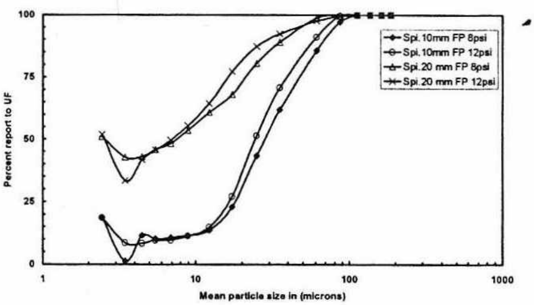

Fig. 5: Effect of Feed Pressure on Cut Size (10mm, 20mm Spigot)

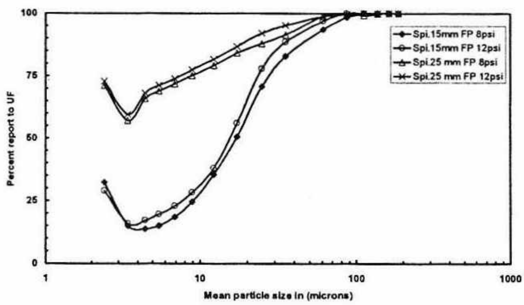

Fig. 6: Effect of Pressure on Cut Size (15mm, 25mm Spigot)

CONCLUSIONS

- Studies on the 76mm hydrocyclone treating fly ash have indicated that a minimum cut size of around 7microns in the product has been achieved by processing the feed with an average cut size (d_{50}) of 35microns.
- An overflow product split varying between 10.0 and 30.0% has been achieved.
- The solids throughput (capacity) was found to vary between 0.45tph to 0.60tph.
- A change in the feed pressure greatly influences the throughput while the chance in spigot diameter greatly influences the split and cut size.

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