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Fly Ash F Morphology and Particle Surface Modification *via* Mechanical Activation

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ABSTRACT

Fly ash F had utilized in many fields, cement replacement, geopolymer, and Nano solid material with endless applications. However, due to its low reactivity, slow hydration reaction and low early strength, the usage of Fly F represented low percentage in admixtures less than 25 wt%. Properties can be modified by mechanical activation to achieve higher added value product. The activation depends on the equipment type and its particle size range of milling. The paper reviewed the milling equipment, and tested the particle size, surface properties, and chemical compositions of activated ash. Increasing in the surface area, pozzolana activity and the reduction of crystalline dense layers of fly ash F, leading to microstructure and structural variations which can be invoked to spread the ash industrial applications.

Keywords: Mechanical activation; Milling equipment; Fly ash; Pozzolanic activity

INTRODUCTION

Sustainable ash management requires the converting waste materials as new raw materials for other industries. Slicate or alumino-silicate based raw materials found in fly ash released from thermal power plant are produced in enormously large amounts worldwide , and its disposal landfill imply environmental and social problems. However, the standard of those sorts of materials is extremely heterogeneous. Therefore, it's necessary to manage and modify their characteristics, to boost the performance of the ultimate product. The modification can be conducted/carried out using various ways such as mechanical, thermal or chemical activation. Coal Fly Ash (CFA) dense glassy surface layer, chemically stable, protects the active inner constituents, which generates low reactivity particle surface. Ash comprises of porous, spongy and amorphous particles. The reliability of the FA can crumble to encourage its chemical activity if the glassy chain, which incorporates Si, AL and low carbon, is exposed to activation methods [1]. Activation methods are utilised to control and adjusts the ash characteristic for specific purpose in some fields [2]. FA applications are often expanding if the ash has larger specific area and finer particle. One of these methods is the grinding mechanical activation, which enhances the reactivity of fly ash through three approaches: I. Mechanical dispersion (size reduction), where the upper reactivity is the result of the increased specific extent, II. Surface activation where mechano-chemical reactions occur on the particle surface, and III. Mechano-chemical (structural) activation, where inner parts of the particle transform to other structures.

Activation of fly ash by milling

The main milling equipment that are accustomed to grind ash into smaller particle size are; rod milling, ball milling, vibration milling, and electromagnetic mill. Ball milling consists of a rotating hollow cylinder, partially crammed with balls, with its axis either horizontal or at a little angle to the horizontal.

The fabric (to be ground), is fed in through a hollow trunnion at one end and an identical trunnion at the opposite end to allow the product to leave through. The outlet is generally covered with a rough screen to stop the escape of the balls and is often loaded with particulate materials with 30%-40% capacity [3]. Rod mills are similar to ball mills, except they use long rods for grinding media and receive feed up to about 50 mm. Vibration mill is filled to approximately 80% of total volume with porcelain or stainless-steel balls. During milling, the complete body of the mill undergoes a very low and frequent vibration, which is generated by an eccentric motor and size reduction occurs by repeated impact. Vibration mills are like ball

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mills therein particles of the materials are crushed between porcelain or metal balls in the mill body. Grinding process in the electromagnetic mill is performed by the ferromagnetic grinding media (small rods), which move in rotating electromagnetic field. Milling or grinding reduces the ash particle size by converting large spherical particles into smaller irregularly shaped particles, which subsequently have a negative impact on rheology. Milling consumes more energy to get the fine particle size distribution and incorporates a size limitation .The advantage of milling is that the whole milled quantity includes only defined particle size distribution rather than fine and coarse particle size distributions. For particles of 50 μm, the energy needed to grind the fabric down to the specified size follows the Von Rittinger grinding law, while the particle sizes greater than 50 μm follows the Bond grinding law [4].

Paper goal

This paper reviews the surface changes of Class F fly ash, when mechanically activated, in particular the specific surface, specific density, mineralogical phases and reactivity properties. Different mechanical activation ways are used to control fly ash characteristics and its application.

MATERIALS

Class F chemical composition

Fly Ash (FA) particles are generally spherical in shape with range in size from 0.5 μm to 100 μm. Class F ash contains more than 70% of SiO_2 , Al_2O_3 and Fe_2O_3 and less than 10 % CaO. FA shows an existence of amorphous glass, mullite, quartz (crystalline silica), hematite and small amounts of lime. The intensity of quartz with mullite forms a chemically stable and dense layer. Fly F silicate, or silicate- aluminate (Pozzolana Material) bosses a small or absent self-hardening, which reduces its utilization to remarkable limit. The hydrated silicate in fly ash develops the strength while the lime fills the voids, by forming CSH, which give the mixture the same cementing properties as Portland cement. This reaction of fly ash with lime in concrete improves its strength. But by increasing of raw class F fly ash to 15% to 25% in concrete, decreasing the cements activity was observed due to the low quantity of CaO. The pozzolanic activity of fly ash increases the compressive strength in later stages, but low strength was observed at early curing time. The microstructure of fly ash F before one year on curing exhibits a copious amount of un-hydrated spherical fly ash particles. To solve the Class F drawback in order to achieve sufficient strength throughout the total stages of curing, it is appropriate to mend the ash surface and reactivity by applying activated methods [5-7].

Experimental methodology

Mechanical activation modifies the physicochemical properties (particle size distribution, Specific Surface Area (SSA), grain phase composition). Particle size (PS) distribution can be determined by dry or wet sieving, sedimentation or laser scattering methods. Specific Surface Area (SSA) of solids is determined by the BET (Brunauer, Emmett and Teller), which is commonly used to evaluate the gas adsorption data and generate a specific surface area result expressed in units of area per mass [4,8]. Chemical composition of FA can be determined by Energy Dispersed X-ray analysis (EDX). Material structure can be identified by Fourier Transform Infrared Spectroscopy (FTIR) in transmission mode. The X-ray diffraction (XRD) technique is used for mineral phase analysis. Morphology and particle shape of the material can be investigated by optical or Scanning Electron Microscopy (SEM) or by Transmission Electron Microscopy (TEM).

RESULTS AND DISCUSSION

The paper reviewed the effect of mechanical activation applying types of equipment .Many parameters within a lot of industrial applications had been reviewed. The necessary per treatments and the studied factors helps the researcher in this field to have summarized view about the mechanical activation research and their changes in fly F properties.

Changes in particle size and specific density

The milling process can be divided into three stages. The first step is the initial grinding period, in which the increase of fineness is very sharp and the time is from 0 to 30 min. The second step is the developing grinding period, in which the increase of fineness slows down and the time is about from 30 min to 50 min. The third step is the delay period and the time is about from 50 min to 70 min, in which the fineness is no longer increasing or sometimes decreases a little. This arises because the particles are so fine that they aggregate together by electrostatic forces. These results are compatible with the remarks. It should be taken in account that, the results of mechanical activation (SSA, PS) depends on the type of activation device used. Remarked that the simple grinding equipment (Rod Mill) is efficient to grind the coarse material only, but it is not so for the fine materials less than 40 μm. Myroslav Sanytky et.al used the electromagnetic mill to obtain ultrafine fly ash contents ≤ 20 μm (more than 90%). Large amount of particles smaller than 1 μm, consisting of spherical silica-alumina grains which contain large amounts of alkali metals.

During the milling process, an increase of specific gravity was recorded. It was clear that grinding for 50 min is a cut-off point, means before this point the specific gravity increased rapidly, while after it, the specific gravity increased more moderately. However, the specific gravity moderated after 50 min grinding. That was because the fineness of the FA eased at this stage. Fineness enhanced the specific gravity rise and this elaborated the increase in cement mortar density when 25 percentage of cement was replaced by milled fly ash, showing that an upgrading on the particle packing of the mortar incorporating finer particle size. For concrete application, the slump increased when milled fly ash added to the concrete admixture .The higher the slump, the higher workability of concrete. Researcher found that 50-60 wt% activated fly ash can be used cement replacement with strength higher or comparable to market cement. The activated Class F ash utilizes as cement replacement in concrete for environmental consideration as it improves the workability, pumpability, cohesiveness, finish, ultimate strength, and durability. For geopolymer the fineness of fly ash plays an important role in improving its properties. The higher workability, the higher strength in early duration of geopolymerization reaction.

Change in specific area and reactivity

Rudolf Hela and Denisa remarked that the grinding in Ball mill for Class F fly ash increased the specific surface area with increasing milling time. Other authors represent the similar outcomes, using BET model, where the variation in BET of fly ash with different milling time increased marginally. As mentioned above, the effect of milling device in SSA increase using ball mill, eccentric vibratory mill and electromagnetic mill in succession. Kumar, Mehrotra established that the Attrition mill had an effect on the increase the fly reactivity by 11% greater than vibratory mill in the geoplimeraization application. Paul et al. considered the particle shape of fly ash. The particle surface is more uneven and rough, the shape is irregular, as compared to fresh fly ash which has particles mostly spherical in shape. This leads to an increasing of dislocations, the disclosure of the active surface and subsequently the surface reactivity found that milling of fly ash affects the surface properties and geopolymer reactivity. Heat evaluation peak as an indicator for an attribution to geopolymerization shifted to low intensity, which indicates an increase of fly F reactivity and that the geopolymerization reaction can be applied at ambient temperature using mechanically activated fly ash.

CONCLUSION

In this paper, mechanical activation of fly F ash through milling was reviewed. Four milling equipment, Rod, Ball, Eccentric Vibratory and electromagnetic mills can be used to reduce the particle size from course to ultra-fine size. The milling time was shortening when higher energy mill was used/applied. Milling or grinding process increases the fly ash reactivity and pozzolanic action. The importance of higher amount of fly F to be utilized in cement replacement, geopolymer and Nano particles applications. The drawback of fly ash F, particularly low strength in early concrete admixture, and low reaction rate in geopolymer had been resolved. In spite that the effect of milling alone did not have sufficient research studies in the adsorption process, since its applied with other activation methods like acidification and alkalization .Modification of fly ash surface properties and morphology, can enhance the application of fly ash to be a valuable commercial products.

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