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IMPACT OF ACTIVATED CARBON ON DUST MITIGATION FOR ASH SILO UNLOADING

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ABSTRACT

The unloading of fly ash storage silos is a process prone to dusting. When fly ash is transported by open-top trucks, dusting in the silo unloading bay is typically mitigated by conditioning the ash with the addition of a carefully controlled quantity of water in a device such as a pugmill mixer. When activated carbon is comingled with the fly ash in the storage silo, dust control can be become more complex. The hydrophobic nature of activated carbon requires a significantly higher quantity of water to get the fine particles to bind with the fly ash and prevent airborne particulate during the unloading process. This paper will describe and characterize the properties of ash and activated carbon, as well as their impact on conditioning. An advanced system for dust mitigation is also described along with a discussion on operating experience.

INTRODUCTION

Ash silo unloading is a process typically carried out by discharging material into a truck. In a disposal plan, the material is wetted in a mixer to a point where fugitive dust is not released during the discharge into the truck, and also when the material is discharged from the truck into the landfill. The addition of powder activated carbon (PAC) for mercury control in a power plant application presents complications for both the wetting and mixing systems. First, PAC is a hydrophobic substance, resisting efforts of the water droplets to capture and agglomerate the particles. Second, the small particle size of PAC allows for relatively low velocities of air to entrain the particles and create fugitive dust.

Fly ash waste materials from a pulverized coal-fired boiler are often cementitious when mixed with water, due to pozzolanic reactions. These reactions cause dramatic increases in the bulk strength of the material, causing difficulty in the wetting mixer, known as a pugmill mixer, as well as issues in the discharge from the truck. These strength gains create practical limitations to the amount of moisture that can be added to the material. Furthermore, over-addition of water may cause excessive free water in the truck, causing *run-off* from the truck during transport. This run-off is considered an environmental discharge, posing significant difficulties for the site and therefore, must be avoided as well. The hydrophobic nature of PAC requires higher mixing water content than would be otherwise necessary with a normal fly ash. In some cases, total elimination of dusting due to PAC cannot be eliminated in the mixer, and secondary measures must be considered to meet specifications.

A material property-driven approach was developed by Babcock & Wilcox (B&W) in conjunction with consultants to systematically identify the material moisture content range that is practically possible within the pugmill mixer, while maintaining reliable operation and minimal dusting. A novel approach was also developed using a moving curtain system around the truck being filled to minimize the air volume required to be passed through a vacuum dust collector system.

MOISTURE CONTENT RANGE

The identification of the optimal moisture content range for operation of the pugmill mixer is based on two principles: minimize dusting and minimize material strength gains.

Dust generation during the truck filling process comes primarily from the falling stream of material impacting a stationary bed of material. There is also a component of the dust that is generated from the air stream experienced by the material as it is falling.

As material strength increases in a pugmill mixer several things can contribute to a decrease in operational reliability and performance. One common example of high strength materials being problematic is build-up occurring within the mixer. This will typically be exhibited as depositions on the pins/paddles and the main shafts. Furthermore, in some instances a material's strength can increase very rapidly and jamming of the mixer can occur when the body is filled with wetted material.

Material Strength

Measurement

For the purposes of evaluating the material strength over a variety of moisture ranges, unconfined yield strength is used as a benchmark. The essentials of this test method include preparing samples of material to different moisture contents then applying the same compressive load to each sample within a confining volume. After application of the compression, the test sample is removed from the volume and a new compressive load is applied. The strength is reflected as the magnitude of the load that can be applied before the test sample fractures. This is a very common form of uniaxial strength testing.

Evaluation

The primary boundary of selecting viable moisture content for operation is by identifying the peak strength and keeping operating conditions below that level. The peak strength occurs when the wetted particles are in physical contact with each other as well as the cohesion effects of the water binding it together.

The curve of the material strength profile leading to a peak can be seen in Fig. 1.

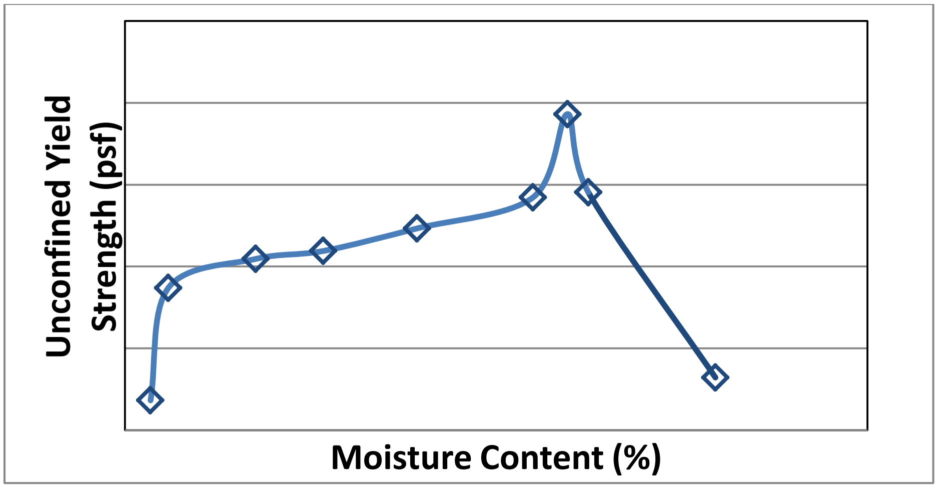

Fig. 1 – Material Strength as a Function of Moisture Content, Bituminous Ash

Due to the inconsistent nature of most operating fly ash silo mixing systems, it is often advisable to not base moisture content at a level just below the peak strength. The operating moisture content can vary by a couple of percent within the mixer's volume due to inconsistent ash feed or inefficient application of water.

Dusting

Background

Dust generation during the discharge of the mixer is analogous to the dust generation phenomenon of a hopper discharging onto a pile. See Fig. 2. The process follows this sequence:

1) As material free falls it undergoes expansion which entrains air.
2) When material hits a surface it causes an impact stress.
3) Material consolidates and squeezes particle-laden gas from the solids' voids.
4) Gas and particles travel down the pile.
5) Most gas gets caught in the eddy at the bottom of the pile.
6) Some gas escapes the bin, hopper, or truck resulting in nuisance dust.

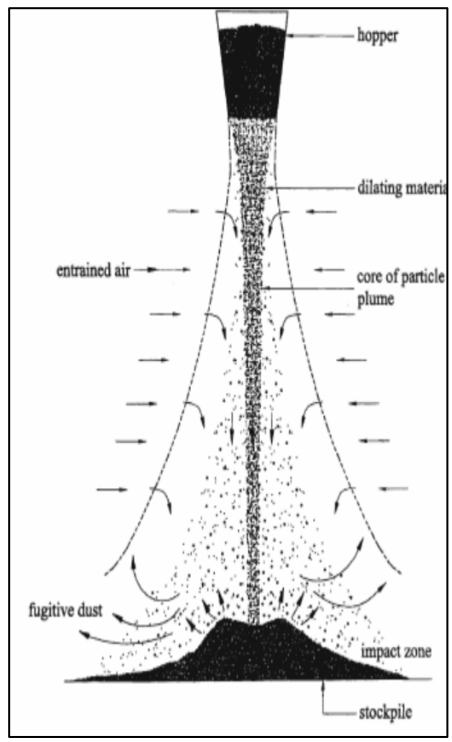

Fig. 2 – Fugitive Dust Generation

Measurement

To adequately quantify the dusting potential of a material, several steps must be taken to arrive at the final method. First, the velocity of the falling material must be calculated. Second, the effect of that falling solid on the bed must be quantified. The third step is to relate the impact pressure back to a change in volume of the bulk solid. This change in volume is derived from the bulk density vs. consolidating pressure curve established when characterizing the material. The volume change calculated at this point represents the maximum amount of material that could be captured by the moving air and expelled as fugitive dust. The fourth step is using computational fluid dynamics (CFD) to determine a characteristic set of gas velocity conditions along the pile (which would entrain the solids as dust) and escaping the bin. The fifth step of the process involves experimentation.

The experimentation aspect of determining an operating range of moisture content relative to dusting is the most straight-forward part. The test setup consists of a cylinder with a permeable membrane at the bottom, and a conical funnel at the top. A small, known quantity of material, conditioned to the test moisture level, is placed in the cylinder and air is passed through the cylinder. After a fixed period of time, the sample is weighed to determine the amount lost during the test time. The gas velocity used in the test corresponds to those found during CFD.

Evaluation

The results of the dust testing can only be evaluated as a comparative test between moisture levels, and not as a predictor for how much dust will be generated during a given cycle. There are too many variables that are assumed in developing the test arrangement to give a reasonable level of accuracy for predicting actual dust generation quantity.

Fig. 3 shows how dust entrainment responds to increasing moisture levels. It is evident from the figure that dust entrainment forms the lower boundary of the moisture content target. From the figure, it would be acceptable reasoning to consider the maximum amount of moisture obtainable in the solids to reduce dusting to the minimal value achievable.

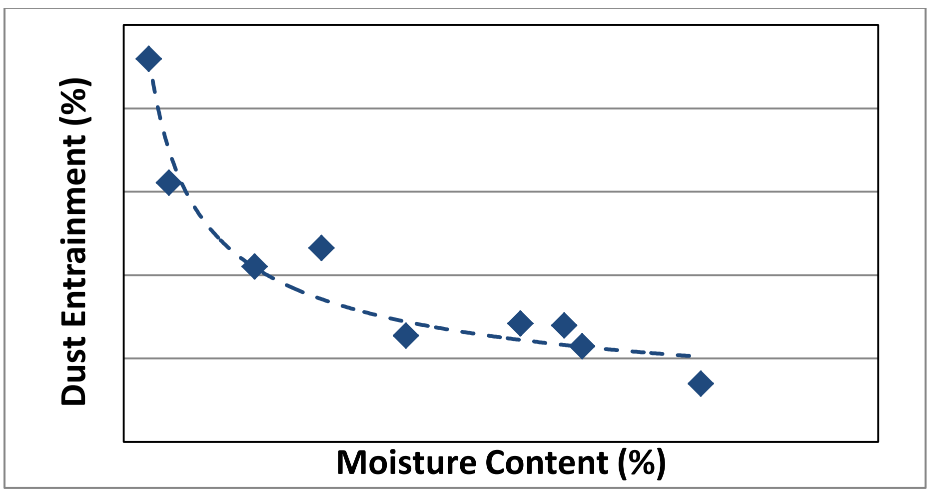

Fig. 3 – Dust Entrainment as a Function of Moisture Content, Bituminous Ash

This is an operational reality that plants currently deal with and adjust for this during operation. Operators typically increase water levels to the point where dusting is not an issue. However, the increased moisture levels often have negative effects not easily recognized by the operators until they are well beyond the strength peak and into the free-water, saturated material zone.

As can be seen in Fig. 4, when comparing material strength and dust entrainment curves, an acceptable operating range becomes identifiable (represented by the yellow bar). While it is certainly possible to deal with the operational issues resulting from operating into the peak strength of the material through increased maintenance and cleaning of the pugmill mixer, it is inadvisable.

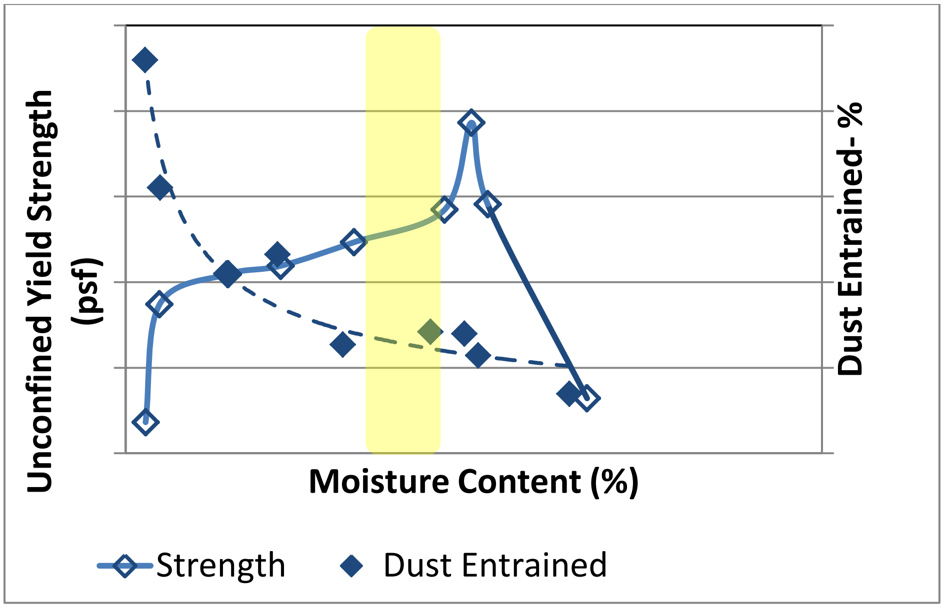

Fig. 4 – Strength and Dust Entrainment Curves, Bituminous

Fig. 5 illustrates an interesting phenomenon that occurs once PAC is introduced into a system. The entrained dust data shows two inflection points. The first represents the moisture level at which the subbituminous ash particles are primarily captured, while the hydrophobic PAC particles are resisting the agglomeration. The second inflection point, at the material strength peak, is the point at which the PAC particles are starting to be captured and bound in the agglomerates. However, with this type of ash, running near the material strength peak is nearly impossible to maintain. Therefore, the best achievable value for moisture content must be used which often, when dealing with PAC, allows for fugitive dust generation.

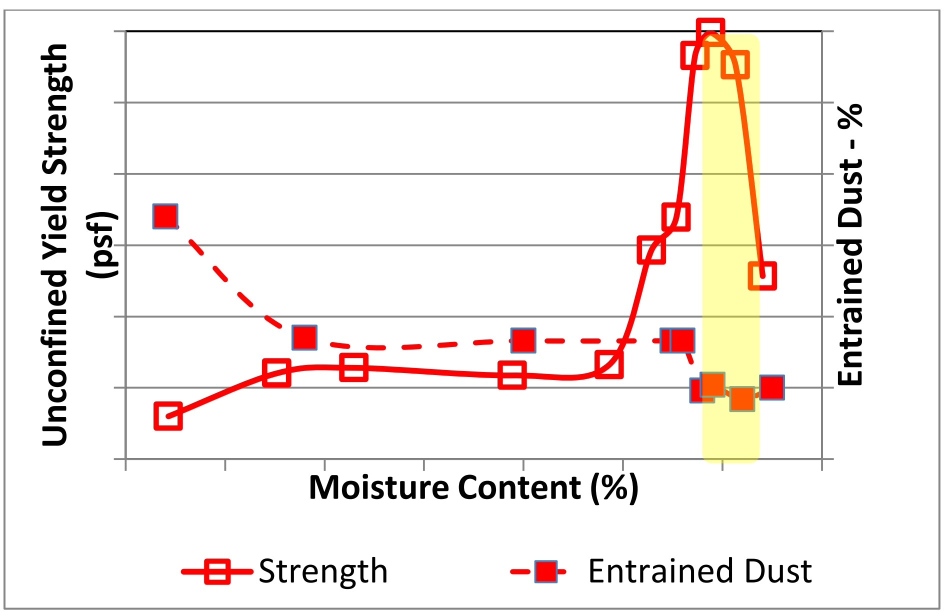

Fig. 5 – Overlaid Strength and Dust Entrainment Curves, Subbituminous/PAC

FUGITIVE DUST CAPTURE

A system to capture the small PAC particles that have become airborne was developed. This system was designed to be used on an open-sided unloading facility and needed to involve no contact with the trucks being used to haul the conditioned material. To meet these needs and constraints, a curtain system was devised to provide an enclosed volume for a vacuum dust collector to be used. These systems are typically used on material conveyor transfer points, with confining hoods to keep the treated air volume as low as possible. As the volume increases, so does the vacuum prime-mover requirements.

To keep the size of the collector reasonable, an innovative system was devised to allow for the flexible curtains to move closer to the truck, and subsequently a portion of the curtains to follow the truck as it traversed under the loading spout. Furthermore, to maintain low manpower requirements, the system is automated in the tracking of the truck. To allow for non-contact, the truck drives through an automated curtain door, which closes behind the truck and comprises the moving aspect of the curtain. Along with the rear door of the curtain moving, the side panels also move closer to the truck when it is in the loading position. This is to help contain the air volume that must be moved to capture the fugitive PAC particles. See Fig. 6, Fig. 7 and Fig. 8 for the arrangement of the curtain system.

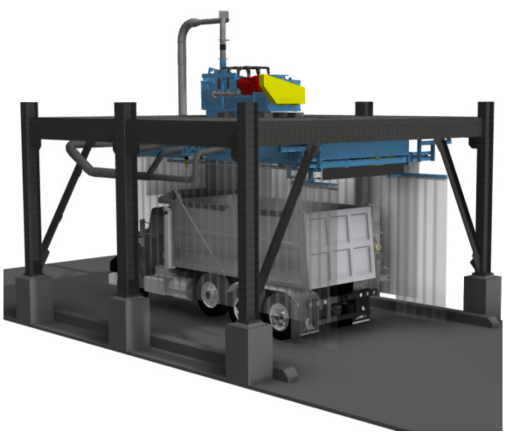

Fig. 8 - Curtains Open for Truck Entrance

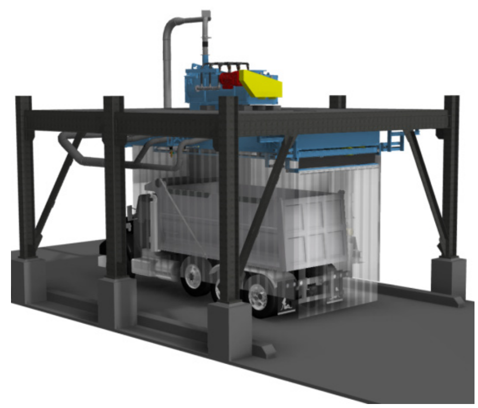

Fig. 8 - Curtains Closed for Filling

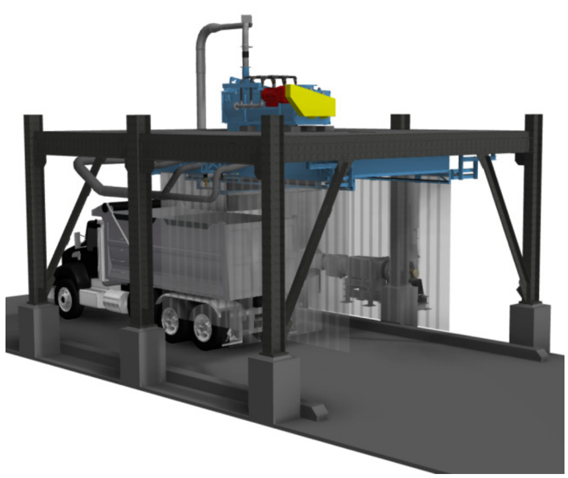

Fig. 6 - Curtains Traveling to Follow Truck

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