Reuse of FGD Gypsum as Pelletized Fertilizer through High-Intensive Mixing

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INTRODUCTION:

Synthetic or FGD gypsum is a high quality, environmentally safe Coal Combustion Product. With the gypsum panel market lagging in some areas, additional gypsum uses becoming available, and additional scrubbers still being added, it is best to pursue alternate beneficial reuse options aggressively.

Agricultural applications for FGD gypsum are clearly established; however, the material in its raw, powdered form limits the marketability area and value of this valuable fertilizer. Although gypsum has characteristics that make it notoriously difficult to process, high-intensive mixing counter-current technology has made gypsum pelletization a practical reality. With the minimal use of water and additives or “binders,” FGD gypsum may be transformed in under six minutes into spheres with appropriate strength and controlled dissolvability, all in one operation. Pelletized FGD gypsum — in this new and stable form — can be readily transportable, and more easily handled, stored and applied, greatly expanding the markets and the region for the CCP producer.

Pure pelletized FGD gypsum is valuable on its own, but high-intensive mixing allows for endless customization of the end-product. The technology produces quick and consistent uniformity using the High Intensity, Counter-Current, Rotating Pan Mixing Action. This mixing action allows for the addition of any number of value-added ingredients. Based on demand, CCP producers may offer pelletized gypsum with urea, humic acid, phosphates and many other solid or liquid additives. The final pelletized product in this batch process can even be customized for specific end-markets or buyers – one system can make several products.
Bolstering the extent of FGD gypsum use is a key to the sustainability of Coal Combustion Products. Exploring the latest technologies that have the potential to accomplish this is an important endeavor.

WHY HIGH INTENSIVE COUNTER CURRENT MIXING

As was mentioned, it is generally difficult to obtain thorough mixing and water absorption of CCP’s. The greatest factors in mixing are mixing intensity and time, with the two factors being inversely interrelated. We have found many advantages with using our Lancaster High intensive mixers with CCP. For example, in comparison with a pugmill operation, even in simple flay ash densifying and dedusting, we have found that water can be cut 50%, saving on water usage and haulage fees, while at the same time providing 10% greater compatibility at the landfill...all because of the more thorough mixing of the particles with the water.

As explained later, this same mixing action if continued with a mix having binding properties will form pellets. This thoroughness of mix also translates into the need for minimal additive ingredients to accomplish a task such as binding to form pellets. Being able to use minimal amounts of binding material also allows for the use of binders that may not be economical when larger percentages are needed.

WHAT IS HIGH INTENSIVE COUNTER-CURRENT ROTATING PAN MIXING?

What Is A Counter-Current Rotating Pan Mixer?
This is NOT a new invention. However, most technical books on mixing equipment rarely include this mixer design. Yet, counter-current rotating pan mixers have been serving industrial mixing needs for over 75 years. So, how is this mixer different from, and perhaps superior to, other mixer designs?

Let's first review a home kitchen mixer. It has a top-mounted agitator and a vessel. The agitator is mounted through a stationary cover and the vessel removable. The rotational axis of the agitator may be fixed or move in an orbit.

We charge the mixer with say, a cake mix and water, lower the cover and turn on the agitator. Sometime after that, we stop the agitator, raise the cover and scrape the bowl to get the unmixed materials near or adhering to the wall or the bottom to where the agitator is for dispersion. We re-start the agitator to finish the mixing step before transferring the wet cake mix to a baking tray, again scraping with a spatula to make sure all the mix is emptied from the bowl.

The above descriptions highlight some critical areas that beg improvement if we were to apply this general mixer design for industrial processes. Without improvements, unmixed or under-mixed materials will remain. And those manual-assist steps, which we don't think twice about when in the kitchen, become big issues when plant operation is mechanized and automated as they are today.

To improve mixing, designers increase the number of agitators or area of sweep. Hence we witnessed the progressive development through turbine mixers, planetary mixers etc. The common feature of these mixers is a stationary vessel and various measures to reduce dead zones either by increasing mixing tools and/or reducing the clearance between the tools and the vessel wall.

As the mixing tools and the vessel wall become closer and closer together in an attempt to engage the layer of unmixed materials, the risk of accidental collision from vibration forces the reduction in speed, hence offsetting the goal to both mix effectively and clean the wall of buildup. Added tools also crowd out the mixer interior. The inevitable observation is: a stationary vessel cannot satisfactorily minimize wall build up and maximize mixing effect.

The recognition of the above problems led to the design of rotating pan mixer.

**General design concept** (Please refer to Figures 1 and 1A above.)

Consider the kitchen mixer again. What if we can mount a stationary spatula against the bowl and now make the bowl turn? Indeed, a rotating pan mixer does exactly that. The rotating pan (i.e. the bowl) runs at a certain rpm that is slow enough to be safe from vibrational collision but sufficient to accelerate the mix materials to the agitator by
placing the spatula at a good location and deflection angle. The rotational speed of the bowl need not be high hence clearance between the spatula (= Side Scraper) and the bowl can be small. The Side Scraper + Rotating Bowl practically eliminate any wall buildup or dead zones in the mixer.

The rotating bowl (= Pan) provides macro material transport. Mixing is performed by the agitators(= High Speed Rotor and/or Plow) which are mounted in FIXED positions. The agitator can be relatively small, as the mix materials are channeled to it by the rotating Pan and the Side Scraper. This design has the added advantage of leaving ample space within the pan for maintenance purposes.

The “counter-current” reference of this type of mixer originally comes from the Plow which is a secondary agitator in the mixer. The Plow rotates at a moderate speed, allowing it to be set close to the Pan floor to prevent material buildup on the pan floor. For applications requiring low to moderate agitation, the Plow alone may be adequate to provide the desired level of mix homogeneity. The Plow also rotates on a fixed vertical axis and counter-current to the rotating Pan. Its function is to create 3-dimensional mixing actions as well as to aid in material discharge when mixing is complete.

The Plow and the Side Scraper working in conjunction with the Pan can discharge a full batch in seconds. In most cases, 90% of the batch will have left the mixer within 5 seconds. It is typical to see no more than 10 pounds of materials left at the end of discharge. On a 3000-pound batch, this is equivalent to less than 0.3%. Other types of mixers can leave as much as 5% between batches.

**Unique Design flexibilities**

Since the Rotor (primary agitator) is not needed for global material transport, it can be custom-configured in shape and speed as well as rotational direction to suit a variety of applications. It can change speed and direction at will if so needed. It also allows for fast liquid distribution without the use of atomizing nozzles.

An interesting and often useful design option is creating preferential material flow directions using various Rotor shapes. A Rotor can induce preferred directional material flows, increasing or decreasing frictional interaction among mix particles. It can create vortex-like downdraft or updraft material motions. Or it can enhance spinning or shearing effects and pelletizing, depending on design.

The capacity to custom-configure Rotor speed enables the processing of a wide variety of materials, from free flowing powders, through plastic to slurries and liquids. This flexibility allows the mixer to input mixing intensity over a wide range, hence the ability to homogenize a batch in fractions of the time required by other mixer types. A Counter-current Rotating Pan Mixer can be configured to input as little as 5 HP per 1000 pounds
of mix at the low end, and as much as over 200 HP per 1000 pounds at the higher end depending on process requirements.

*Counter-current Rotating Pan* mixers can be the equipment of choice for mixing, mix-pelletizing, reacting, de- dusting, slurrying, scrubbing, plasticizing and a long list of other applications.

Please refer to “Mixing Intensity vs. Mixing Time” for a discussion on the titled topic.

**HOW DOES COUNTER-CURRENT MIXING APPLY TO CCP PRODUCTS?**

*Mix-Pelletization in Lancaster K-series High Intensive Mixers*

Most powders having the ability to fuse, or slightly dissolve in the presence of a liquid can be granulated quite easily. Others may be coax to form granules by the introduction of some suitable binder. The binder may act as a medium for the solid particles to adhere to each other by modifying interfacial activities. Some may form a matrix to capture the particles. Other may involve chemical reactions to achieve the objective.

Size-enlargement in the powder technology context includes: agglomerating, pelletizing, granulating and briquetting. We are going to touch upon particle enlargement generally through a snowballing mechanism, with some shear action, but without the application of high pressure or extrusion.

We will first describe a common “build up pelletization” process:

**Disc / Pan Pelletization:**

One method used to pelletize Synthetic Gypsum is the Pan pelletizer.

Disc pan or disc pelletization is a continuous process. In its simplest form, powders and liquid are fed in steady streams and fixed proportions. In the case of liquid, it is generally sprayed to facilitate distribution, since disc rotation has no tangible mixing effect.

As granules form and grow, the larger ones percolate to the surface of the bed in resulting in size stratification. The rotating disc is tilted at some angle to enable continuous overflow of the larger granules. Generally, disc pelletization produces relatively uniform-sized granules.
Instantaneous steady-state mass flow must balance for continuous granulating processes. However, as with many continuous processes, truly steady-state conditions are fleeting for disc pelletization, requiring periodic, if not frequent, intervention.

Disc granulators are primarily single-purpose devices in that by nature of their operation, they take fine particle feed and grow them into larger spheres. For processes involving multiple powder ingredients, disc granulators will need a mixer to handle the mixing aspect. In those cases, a workable system will position some type of mixing device upstream of the disc granulator to first thoroughly mix the powders before feeding the device.

**Mix Pellitization:**

As the name suggests, mix-pelletization operations integrate the need to mix multiple ingredients to produce granules of desired properties. If the mixer-granulator can output adequate intensity, it may also be effective in breaking up lumpy feed before proceeding with mixing and pelletization. This de-lumping capability also means that the raw material does not have to be dry, but can be moist as when coming from a pond or a filter press.

The ability to segregate operational stages within a batch allows the mix-granulator operation to be automatic, with little operator attention. The process produces consistent product properties batch after batch.

Some benefits of integrating mixing and pelletization in the same device are reduced capital expenditures, operational savings, and space savings.

With LANCASTER K-series mix-granulators, the resulting granules cover a wider spectrum of sizes, from micro sizes to as large as 8 -10 mm depending on requirement and feed material. Because of higher shearing and configurable tool actions, granules are generally packed more tightly, stronger and require less liquid/binder. Other properties can be controlled to a significant degree according to the objectives desired.

Mix-pelletization also has the flexibility of approaching the final moisture content either from the dry end or from the wet end. If it is desirable for some reason, an overly wetted batch can be recovered by adding more dry ingredients, thereby bring the moisture level back to optimum for granule formation. In practice, there are operations in the domestic market deliberately making use of this ability.

As LANCASTER mixers are capable of inputting intensity and energy independent of mixing-granulating time, a number of factors can be adjusted to influence granule characteristics. These mixer configurable parameters include: rotor design, rotor speed, direction and granulating time, pan speed. In addition, optimizing process parameters
such as solids fineness, binder, liquid-to-solids ratio, liquid addition rate can enhance desired granule properties.

LANCASTER K-series mixers are especially useful for processes where some multi-ingredient solids need to be well mixed and then granulated into spherical products. Mixer and process parameters can be controlled to achieve desired properties. Size distribution usually follows a bell-shaped curve, with approximately 90 percent of granules falling within one order of magnitude.

**A typical Mix-Pelletizing Cycle:**

The following steps are typical in a mix-granulating cycle:

1. Charge solids
2. Dry mix and de-lump (this step may be skipped with single component powder feed)
3. Add liquid
4. Wet mix and form seed
5. Granulate
6. Dusting (to stop granules growth and clumping together. Optional)
7. Discharge

While the above steps have been presented as distinct stages, they do overlap. For instance, depending on one’s perspective, wet mixing can be considered commencing...
as soon as the first drop of liquid contacts the dry ingredients. Also, some seed formation may already proceed while liquid is still being added to the mix.

A door-to-door cycle can run anywhere between 3-4 minutes to over 10 minutes, depending on raw materials, process, and product requirements.

**Peripheral Operations:**

Many productions can utilize the entire batch in downstream handling. Others may require a narrower cut, hence necessitating a screening and recycling step. Still others may require some type of drying, conditioning or calcining step to achieve their final properties.

An example of mix-granulating plant may appear as illustrated below:
HOW ARE SYNTHETIC GYPSUM PELLETS MADE FOR FERTILIZER APPLICATION?

The high intensive Counter-Current Mixer can produce the pellets needed for an agriculture fertilizer, but how do we get there? The first step is the raw materials. If the raw gypsum is dry, the process can begin. If it is moist beyond about 10% we’ll also need to have some dry product available to dry out the raw material to about 10%. Dry gyp or other dry powders may work for this moisture absorption. The final material needed is a binder for the gyp. This may be a liquid or a powder. We are currently using a 0.5 percent concentration of an organic liquid binder. This binder allows for pellets strong enough to withstand handling and storage but yet dissolve in the required time.

The first step in pellet production is to charge the mixer. Pre weighed raw materials are added to the mixer for a “dry” mix time. The water and/or liquid binder is then added to the mixer and mixed with the powders during the “wet” mix time. During the wet-mix time, micro—pellets begin to form. The final period of the cycle is the pelletization process of growing the pellets. Generally, the longer this process is, the larger the pellets. The final stage of the mixing cycle is the quick discharge from the bottom of the mixer. We have found that a total mix cycle of approximately eight minutes can produce gypsum pellets with a range of .25 mm to 6 mm in size.

After the pellets are discharged from the mixer, they generally fall into a surge hopper under the mixer. From there the green pellets are metered onto a conveyor belt. The pellets then enter a dryer. From here the pellets can go directly to bulk storage or be screened and segregated by size for various applications and conveyed to a bulk bag loader or a 50# sack loader. The final fertilizer product is then ready for sale in bulk or bulk bags to farmers and in 50# bags for commercial sale.