PROCESSALL

The Development and Use of Fluidized Bed Plow MIxers

Background

Over the last 20 years, plow mixers have revolutionized the solids mixing industry by presenting an intermediate range of mixing technology to the industry. Prior to this period, solids mixing was broken into two classifications, low and high intensity. Low intensity mixers (usually called blenders) gently mix and fold the product, generating very little shear and heat but doing a somewhat minimal job of mixing as measured by process time and particle distribution. High intensity mixing, on the other hand, accomplished the mixing in a relatively short time but at the expense of particle degradation (shear) and heat input due to mechanical energy buildup. In brief, the application of shear typically increases with the intensity of the mix action, and thus the drawback occurs.

Theory

The mechanically fluidized plow blender opened a new era by providing a means for quick, intense mixing without the application of high shear. This is done using a method called particle fluidization. Particle fluidization, by definition, is the separation and agitation of solid particles using a rising stream of process gas. Mechanical fluidization is a process of separation and agitation of the particles using the impingement of the product on a rotating element. This is usually done in a cylindrical horizontal vessel which contains a rotating shaft. On this shaft are a series of rotating elements (plows) which are designed to lift and separate the product inside the vessel. The design of the blades, the number and spacing of the elements, and the speed all contribute to fluidization. When done properly, all particles are rotating in a torus, moving in three directions while intermingling in suspension.

The sum of this technology is that given the proper design of the blades the product is lifted in such a gentle manner that very little shear occurs (even though the mixing action is very intense). The advantages of this over a gas fluidization are many. Inside the gas fluidizer the gas becomes the controlling factor, bringing along with it problems dealing with complex fluid mechanics. Furthermore, the suspension of particles using compressible fluids is inefficient both in the propulsion of the particles and the conditioning of the propellant gas. Inside the mechanical fluidizer the fluidization is directly controlled by the rotational speed of the agitator; this becomes a simple mechanical variable to command.

Application

The applications of this technique are many. Because of the gentle yet intense mix action in a hermetically separate environment, a perfect condition exists for a variety of chemical processes to occur.

By its nature this environment provides the most intense mix action available. This action is excellent for both solid and multi-phase mixes. Mix ratios of up to 1:20,000 are possible. Mixing occurs in a very short period of time, usually minutes. Mixes of over 600,000 centipoise are possible. The reason for this is twofold: the mix is fluidized (therefore assimilating the mechanics of a fluid) and at the same time is being rapidly agitated in three dimensions. Three of the most popular applications; particle granulation, drying, and reactions, account for the majority of installations throughout the industry.

Particle Granulation

Because the particles are suspended, there is a maximum particle surface area exposed to the process. Small amounts of liquid can be injected to coat the particles in an exact and consistent manner. A binder liquid can be applied to cause the particles to agglomerate. The major advantage of this method of agglomeration is that it generates more shear and particle to particle contact; therefore less binder is used and stronger agglomerates are
generated. Another advantage is the ability to process sticky products. High speed mills quickly disperse the liquid evenly throughout the mix. Typical batch cycles are usually less than 10 minutes. The granulation can then be dried in the same vessel (see below).

Vacuum Drying

Three variables, heat transfer, surface area, and vapor pressure, affect the removal of moisture from solids. Vacuum drying is the most efficient form of product drying known. By reducing the vapor pressure moisture can be vaporized at a lower temperature using less heat energy than boiling at atmospheric. Drying in a gas fluidized bed dryer is difficult because the vapor pressure must be increased to suspend the particles. In a mechanically fluidized bed dryer the movement and suspension of the particles is independent of vapor pressure. Therefore low vapor pressures (high vacuum) can be achieved by correctly sealing the vessel.

Vacuum drying in a low intensity blender is slow because the particles (or paste) are not efficiently exposed to the low vapor pressure or to the heat transfer media. Because tumble dryers, vacuum dryers, ribbon blenders, merely stir the product, only certain areas are exposed to the low vapor pressure at any given time. In a fluidized bed, with all the particles suspended, maximum surface area is exposed to the low vapor pressure. Heat transfer is the final variable. Gas fluidized bed dryers utilize the propellant gas along with a heated container shell to transfer heat into the product. This transfer, because of the intimate product to gas contact, is highly efficient. The gas, however, must first be heated by a steam coil which adds another step into the heat transfer equation. In low intensity blenders the product is stirred and eventually will come in contact with the heated vessel walls. Product particles in the mechanically fluidized bed dryer, because of the intense mix action, “visit” the walls of the vessel at a high rate and therefore pick up heat quickly.

A final factor which must be dealt with during drying is the formation of agglomerates during the process. When this occurs, the outside shell of the agglomerates become dry and somewhat impervious, shielding the moistures inside from both the low vapor pressure and the available heat. The drying process at this point levels off, with little moisture being removed. The natural mechanical action inside the vessel will eventually break these agglomerates, exposing the inner moistures to the low vapor pressures. Unfortunately, this process comes at the expense of time and energy. Some mechanically fluidized bed manufacturers offer high shear mills (choppers) which are inserted into the mix at right angles to the rotational flow. These mills, with correct blade design, can be used to break these agglomerates as they form, keeping the moisture exposed and therefore lowering the overall drying time. Depending on the product nature, these mills can be quite valuable.

Reactions

Within the fluidized bed mixer, with maximum particle intermingling and maximum heat transfer available, a perfect environment for reactions exist. Again, this action is entirely independent of vapor pressure; thus pressures can be increased either through gas injection or exothermic reactions. The ability to vary the pressure while maintaining these conditions makes this type mixer a very efficient chemical reactor. Products can go through various theological stages while inside the mixer with little effect on the mix action. Liquids, solids, and gases can be combined inside the reactor in the most intimate manner under the most optimum and exact temperatures. Given the correct design, the vapor pressure can then be lowered, enabling the vessel to dry as well as react. In many instances, a product can be completely manufactured from its basic ingredients without ever leaving the process vessel. This becomes increasingly important if some of the ingredients are noxious or detrimental to the environment.

Design

While the basic action remains the same, a number of design changes are required to utilize the mixer as a granulator, dryer, reactor, etc. For most applications these involve blade changes, shaft seal changes, vessel structural changes (to accommodate pressure and vacuum), as well as ancillary attachments such as vacuum filter stacks and solvent recovery systems. For granulating and coating, the mixer must be equipped with nonclogging injectors designed to correctly disperse liquid ingredients into the fluidized bed cloud. Many times high shear mills are used to help disperse this liquid. To correctly apply the liquid, the correct design and positioning of both the injector and mill are critical.

When using this type mixer as a dryer, it is very important to seal the vessel as much as possible in order to maintain a high level of vacuum (low vapor pressure). Vapor pressures of less than .1 atm (784mmHg) are typically required for these dryers to be efficient. Therefore mainshaft mechanical seals and even mechanical mill seals are required to prevent excessive air leakage. Access door and discharge valve design also greatly effect the level of vacuum achievable inside the dryer.

It is important to note that leakage’s through these areas, along with lowering the overall level of achievable vacuum, also can affect the design of downstream solvent recovery equipment. The percentage of atmospheric leakage into the vessel equates to the percentage of non-condensable gases being passed through the liquid condenser. Excess leakage rates load it down and require a larger sizing of both the vacuum pump and condenser to handle an equal amount of solvent. Failure to allow for these leakage’s can produce inefficient solvent recovery systems which pass uncondensed solvent into the atmosphere.

Process objectives also define different agitator styles. Some blade designs maximize mix efficiency and are used when low mix times and high mix ratios are required. These are generally the two direction plow style, designed to separate and propel the particles in two separate directions. Another style is the heat transfer, or scraper blade. These propel in one direction only, but provide more scraping action and tend to enhance heat transfer.

Manufacture

There are several manufacturers of this style equipment in the industry; among these become discernible differences in both their design and structure. When purchasing, it is important to note some of these differences. Many blenders tout themselves as “fluidized bed mixers”. Some are merely a redesigned ribbon blender or paddle blender. The paddle or ribbon has been replaced with a series of plows, but the speed and horsepower have not been increased. The resulting configuration becomes less efficient (although more cleanable and appealing) than the original design. The material is merely stirred back and forth as the agitator rotates through the material. Some mixers call their action “fluidized zone mixing”. Usually these are typically a dual element paddle mixer, designed to throw the material upward so that the material in the upper center of the blender becomes suspended. Only a portion of the product is fluidized at any given time, and this accounts for the less efficient results achieved using this design. The true fluidized bed mixer fluidizes the complete product bed, thus the reason for their high efficiency. This is indicated by higher applied horsepower’s and rotational speeds, as well as beefier construction throughout the vessel. Even among the true fluidized bed manufacturers there exists a hierarchy.

Construction

Because of the higher horsepower’s and torque’s involved, good design practice dictates heavier wall thicknesses and stronger bearing supports than normally seen in a blender.
Many manufacturers are prone to incorporate stainless clad carbon steel vessel walls and agitator shafts as a method of cost cutting. Because of the joints required and thin gauges involved, there becomes a very real potential of iron oxidecontamination over the life of the machine. The better fabricators use only solid stainless in these areas.

Does the manufacturer offer mechanical seals? Packing glands, although used for years in the blender industry, are a constant maintenance problem and cannot seal the vessel tight enough to generate the high vacuums required for drying. How available are the seals and does the manufacturer offer a quick turnaround should one fail?

What type of discharge does the fabricator offer? Most blenders use a paddle style discharge. This style, although easy to fabricate, requires elastomers to seal which often become damaged with the opening and closing of the valve. At best this valve can only stop flow; it is not a throttling or control valve. A better valve is a hemispherical or ball valve. These valves use a shearing method to close, eliminating the need for elastomers and allowing, with their action, a natural throttle. The problem with these valves is that they must be designed correctly to mount as close to the vessel interior as possible. The better fabricators design and build their own valve in an effort to minimize this dead space.

Another area where design differences occur is in the heating (cooling) jacket construction. Many fabricators employ dimpled or half pipe jackets to heat the shell of the vessel. This indeed is a lower cost jacket than other designs. The problem is with heat transfer. From 20 to 50% of the area in a dimpled jacket is utilized to weld the jacket to the vessel wall. This reduction in available heat area drastically lowers the overall efficiency. A better method (albeit more costly) is to use a baffled jacket designed for controlled flow throughout the jacket wall. No other design will match the efficiency of this design.

These are some of the many areas where differences occur in design and construction. These differences result in a significant spread in the prices between different manufacturers. The initial price, however, often becomes secondary to the ongoing maintenance, performance, and energy penalties paid by purchasing a lesser design.

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Summary

The overall success of a mechanically fluidized bed process system is very much dependent on the correct application of the device, as well as the final configuration of the machine designed to do the job. Agitator design, seal design, charge and discharge configurations, horsepower, heat transfer devices, ancillary equipment all contribute to the attainment of a good installation. The final configuration of this type of equipment is very much dependent on the manufacturer's counsel. Much of this information can be developed through pilot plant testing. A large part of the brand decision associated with purchasing a mechanically fluidized bed plow mixer comes from a processor's comfort level in working with a certain manufacturer. There is usually much development work and attention to detail required in this type purchase; the ability to work these details with the manufacturer can greatly affect the success of the project.

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