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Grinding Media Selection

In order to do a good job selecting media for your mill, you must consider the type of mill being used, and what is and is not important to consider. For this reason, this subject will be broken into two sections: Vertical Mills and Horizontal Mills. The following information applies to both types.

First, we must agree that all components of the mill influence the way it runs. If it is important to select the type of media then it also must be important to formulate the product correctly for the mill, feed it at the correct rate, and apply the correct amount of energy. In other words, be it resolved that the formulation is part of the mill. Moreover, we should agree that the fourth law of thermodynamics is alive, well and working in your mill. That is: That all available (generated kinetic) energy input will be sinked in one form or another, and the way it is sinked will influence the way the mill will operate. In any given milling operation, a portion of the main and pump motor's horsepower will be sinked as shear force and heat, a portion will be spent in the drive devices (belts, pulleys, etc.) and the rest will be put to work in the process of de-agglomeration. The proportion of the energy going to the work of de-agglomeration is depressingly low, in keeping with a device that works by transferring energy first through drive belts, then through bearings, then viscously coupling it to the material under process with disk, then finally to the agglomerates via the formulation. Every stage of the process is "lossy", especially the hydraulic coupling to the particles in the premix. Transfer efficiency even in the most efficient horizontal mills is generally in the area of 3% to 5%.

The object in selecting media to optimize the mill is to increase this transfer efficiency. In order to get a feel for his, however, you have to know what goes on inside the different types of mills.

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The first most important thing to remember is that your formulation is part of the mill. What is your formulation like? How does it act under shear? More precisely, is your formulation thixotropic, Newtonian or dilatant? A thixotropic material will decrease apparent viscosity under shear. A Newtonian material's viscosity is unaffected by shear. Dilatant materials increase apparent viscosity under shear. Of all of these types of materials, the best kind to run in any mill is one which is slightly dilatant, because all other things being equal, it can sink more energy due to its higher apparent viscosity. Far more common is the thixotropic premix, however.

With this type of premix, media selection is important in decreasing mill wear, since when energy is applied, viscosity drops and more energy is sinked to the mill itself. Newtonian materials, almost by definition, are homogenous and seldom need processing in a media mill. Formulating to imitate Newtonian materials is often advisable in a media mill with insufficient cooling capabilities.

Media Selection for Horizontal Mills – The Basics Most media for horizontal mills is more or less spherical, has certain surface characteristics, and has a specific density depending, of course, on the material from which it is manufactured. Materials include lead-free glass (usually soda-lime due to its tensile strength), Zirconium Silicate, Zirconium Oxide, hardened and non-hardened steel shot, chrome and stainless steel balls and advanced ceramic materials like Yttria stabilized zirconia. Common sense would say that the most expensive would be a whole lot better media than the cheap-o stuff. Not necessarily so! It depends on your mill and the product that you are running.

First, let's look at the material that is being processed. The first critical decision that you must make comes after determining the total solids level of you formulation. For most paint folks, this includes pigment and filler solids and resin solids. Determine the percent solids. If the number in this step is below 25 percent, the best bet is to reformulate to a higher solids level. Assuming that the material is between 25 and 100 percent solids, then make a sample and test the viscosity on a Brookfield to get some idea of what its static viscosity is. Materials above 25,000 to 30,000 cps viscosity (unless they are highly thixotropic) will probably be impossible to process in a standard-configuration horizontal mill with agitator disks and normal internal volume. A good operator can use some tricks to get it to run, but it is not something he would want to do every day. In regard to running very heavy thixotropic materials, not all mills are created equal. To do this type of formulation successfully, the best possible easier to separate the media separator (which imparts considerable shear, making it easier to separate the media without causing mill wear,) and an agitated discharge housing, (to keep the material from setting up after leaving the high shear zone, causing mill pressure problems.) So, now we have a formulation which is over 25% solids and below 30,000 cps. What media do we use?

Types of Media

Well, it still depends…on the properties of the media. Among these are shape (or sphericity), surface effects and density. Sphericity is the degree of perfect roundness that the media displays. Certain types of media tend to be rounder than others. In a horizontal mill, this makes a difference. Most doped ceramics, for instance, are pressed in rotary molds and sintered into spheres in an electric furnace. This media is nearly perfectly spherical. Zirconium Silicate and Oxide can vary quite a bit in sphericity, and often tend toward a teardrop shape, which is far from optimal in a horizontal mill. Even closely graded media will display this tendency. On the other hand, some Silicate and Oxide are very spherical, because they are made in the same way as a doped ceramic. This media tends to be a bit more expensive, but is considerably more effective in a horizontal mill. Steel shot is generally made by spraying molten steel down a tall

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cooling tower, then collecting the shot at the bottom and classifying it according to size. After this, the media is normally "beaten" in a hammer mill – type device to bread apart "dumbbells" (two teardrop shaped beads joined at their pointy ends) and generally wear off gross surface irregularities. If this media is used without the beating step, the product under process will pick up all of the media fines, as the media will tend to wear round in the mill. These fines contaminate the product and tend to clog screen-type separator devices, so it is best to eliminate them prior to loading the media in the mill. Glass can be manufactured to a high degree of roundness, but its density is fairly low. Density does not matter as much as roundness in a horizontal mill; since the force of gravity is not considered an important limiting factor to horizontal mill operation. Defects in glass beads are more likely to negatively influence the life of the media than in other types. Bubbles of air inclusions of foreign material or internal fracturing ("shiners") can cause media fracturing. Surface fracturing causes the media to look "milky", or frosted, and media thus affected will wear at an accelerated rate.

Media Surface Effects

In addition to these properties, media also exhibits different levels of surface activity which is directly attributable to the type of surface finish which is on the media. Porosity or pock-marked, irregular surfaces on the media has an additive effect on the milling process caused by surface cavitation as the fluid under process is forced around the bead. Beads with the most surface effect are of the pressed and sintered variety, as sprayed or rolled media ends to develop a smooth, shiny outer surface. The effect of surface cavitation on mill efficiency is minor, but the downside of using this type of media is accelerated mill wear because of the increased abrasion of the irregular surfaces. Also remember that denser media is usually made by the press and sinter method, and it is more prone to unwanted mill impact in the first place, so the effect is additive.

Media Size

On the horizontal mill, there is the effect of media size. We touched on this earlier, but it is good to restate it now. As most of the work in a horizontal mill is done by squeezing the material through the gaps between the media, it makes sense that the more the gaps, the better the milling. In order to increase the number of gaps, one needs to increase the number of beads. Assuming that the percentage media loading is maintained as a constant then the only answer is to decrease the diameter of the beads. Some constraints need to be placed on the application of this theory, however. Initial premix particle size has a considerable bearing of its effectiveness. If the intermediate space in the operating mill is smaller than the incoming particle size of the premix, the mill becomes a filter, and the mass of the particles tends to push the media to the discharge end of the mill. In mills that are designed for this type of operation, very small particle sizes can be had. However, standard horizontal mills will grind themselves up in this type of duty, much as they will if the mill is packed-out hydraulically. In order to use very small media, (0.50 mm or smaller) you must have a very good premix indeed.

Media Selection

The bottom line in media selection for a horizontal mill is to use the smallest, roundest media that you can afford, irrespective of the density and material type of the media.

Sphericity

For this sphericity discussion, I would like to propose an experiment. As we all know, oblateness, or “eggyness”, causes media tumbling in the mill. The reason for the tumbling is that the oblate shape causes inconsistent distribution of energy on the bead’s x, y and z axes. For the moment, we’ll spare you the vector physics that proves this, but it can be demonstrated easily. Find a shop vacuum. Install the hose on the discharge of the vacuum, and put the discharge nozzle in a vice to stabilize it. Locate a child’s play ball about 3 ½ to 4 inches in

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diameter. Lighter is better, and the best weight is about 3 ounces for most shop vacuums with ½ HP motors. Also secure an oblong object about the same weight and diameter – a L'eggs container that has been glued together will work well. Make sure that the nozzle is plumb and level in the vice. Turn on the vacuum, so that a stream of air is blowing out of the nozzle. Ever so gently, suspend the ball in the air stream. It will find its own level on the column, then stay suspended at the same place, seemingly levitated on the column of air. Now try this with the oblate spheroid. It will be suspended for a short while on the air column, but it will then begin to tumble and gyrate, eventually falling off of the column.

This is the effect of media tumbling in the mill. With the ball and the vacuum cleaner, we are concerned with aerodynamics. In a mill, we are concerned with hydrodynamics. CD (or drag coefficient) is the important variable with the vacuum. CD's hydrodynamic analog, viscosity, is the important variable in the mill. The surface area of a pure sphere is the same in the object's x, y and axes. An oblate spheroid, on the other hand, has different exposures in the x, y and axes, which causes the energy to be distributed disproportionately across the body, creating dynamic instability. Having media displaying tumbling behavior in an enclosed space causes many problems, but explains one peculiar problem. It explains the phenomenon of all media shapes wearing round. In case you never noticed, all media tends to wear into a spherical form, rather than wearing uniformly so that the original oblate media ends its life as a smaller analog of itself. Media tumbling exposes the pointy ends to more abrasion, since the pointy end tends to whack into other media as it tumbles. For this reason, media always tends to wear round no matter what shape it starts out as. This same tumbling causes the space around the media to be different form bead to bead, creating wide and narrow passages in the media bed. Product will flow preferentially through the wide spaces, considerably lowering the composite shear in the grinding chamber. So, get the roundest, most uniformly sized media you can afford. As we mentioned before, density does make a difference here, so factor this into your decision.

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Remember…tumbling (or non-spherical) media displays non-homogenous inter media spacing, which allows the product to bypass the high shear (smaller) gaps and pass through low shear (wider) gaps. As a result, composite mill efficiency plummets. Although this effect in a vertical mill is far less debilitating than in a horizontal, the benefits of round, uniform media are noticeable and worth striving for.

Density

Media float and the screen blinding that it causes are the worst enemy of the vertical mill. This is a phenomenon where the media is carried to the top of the grinding cavity by the product flow. In a horizontal mill, this would be called hydraulic packing. There are several ways to solve the problem of media float, so the mill user is not without options. The first and easiest way to solve the situation is to use media of higher density, which will have less of a tendency to float in the first place. The next thing to do is to lower the product pump speed, as the velocity of the millbase through the grinding cavity can also cause the media to rise in the chamber, much as increasing the volume of air being discharged in our vacuum cleaner model a few topics ago caused the ball to rise higher on the column of air. If you decide to solve your media float problems through going to denser media beware of several complicating factors. A denser media, because it is “heavier”, will tend not to fluidize as easily, and will tend to take more power to start up. This is normally not a problem, but it does exacerbate an existing problem with vertical mills. That is that they are not as energy efficient as horizontals. When they are started, they must overcome the force of gravity. Normally, a vertical mill will require between 95% and 115% of rated agitator horsepower to start, and then fall back to 50% - 70% to run. Many older plants are close to their maximum power grid usage, and may not have enough power to start a really dense media load. Of course, most people do not start all of their mills at one time, even if they are cascaded. Loading an electric motor to over 115% of its rated shaft

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horsepower for more than a few seconds is pure folly. Before changing to denser media, make sure you have the power to start it. In addition, if you have sealed your mill, you can enjoy the benefit of loading a greater media volume. This can make startup horsepower problems much more sticky.

By way of practical example, a typical "sandmill" of the 30 gallon size generally comes equipped with a 40 HP motor, which is fine for a 50% charge of silica or glass. It is even O.K. for a 50% load of zirconium silicate or oxide. 40 HP is marginal for a 65% load of these denser medias, however. It will also absolutely not work with steel shot. For steel shot or hardened stainless balls, 50 HP is required.

Surface Effects

Surface effects are influential in vertical mills much as they are in horizontals. One must be wary, however, especially when switching to a denser media with increased surface effects. A example of this would be switching from glass to zirconium oxide. Your grind will surely improve in most cases, however zirconium oxide is several orders of magnitude more abrasive than glass because of its "nooks and crannies." Being denser, it will tend to stay in the bottom of the mill, particularly with a low viscosity premix with hard-to-grind components, like a waterborne airdry or electrophoretic primer. This will cause accelerated lower shell wear as well as reducing your balance pulley to the size of a hockey puck in no time. Be careful. In general, the less viscosity exhibited by the premix, the lower density and lower surface effect you want from your media. There are, however, several manufacturers who provide zirconium silicate which is only slightly denser and has much greater surface effect than standard. This gives you the best of both worlds.

Media Size

Media size is less important in a vertical mill than in a horizontal, but does have an effect on the

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final grind. It follows form what went before that smaller, denser media, in keeping with the premix viscosity is the best way to charge vertical mill. Most vertical mills can easily be adapted to run media down to .7 mm and above. Again, size consistency is most important here. The narrower the size range of the media, size for size, the better the mill will perform.

Media Selection

You should select the media for a vertical mill in much the same way that you do for a horizontal. Be aware that media density can either be your best friend, or your worst enemy depending on your premix viscosity. Your vertical mill has some performance limitations caused by the mill's orientation but in the real production-floor world, these can be easily overcome by various means.