MATERIAL SIZE CONTROL THROUGH AGGLOMERATION

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ABSTRACT

Agglomeration is an old technique. Awareness of its value is just beginning to be realized in industries outside the iron ore ranges. Upgrading size of fines created during process phases enables more complete utilization of raw materials and is a method for diminishing environmental problems.

This paper outlines many of the techniques available with special emphasis on pelletizing and related techniques using pelletizing equipment.

A simple explanation of what takes place in the pelletizing equipment should enable better evaluation for the use of this rather simple process technique.
SIZE CONTROL THROUGH AGGLOMERATION

Most often, when the subject of size control of bulk solids is discussed, size reduction is what first comes to mind. Particularly in the mining and quarrying industry, size control is primarily a concern of size reduction. Sometimes, this means going very small to obtain mineral liberation.

We are rarely content with the size of the bulk solids we must work with. We crush, grind, pulverize, screen and re-screen until we arrive at a material size considered most economical or desirable for the particular process or product we are dealing with.

In the matter of course, either accidentally or purposely, we end up doing more size reduction than is desirable with large quantities of material or product too finely divided for further economic or practical processing, use, handling or even disposal. What was until all too recently considered a disposal problem was in reality unused or wasted resources. Now with increasing frequency these materials are being reclaimed through agglomeration.

Agglomeration is an old idea to many of us, but new and unexplored to many more of us and universally miss-spelled by secretaries everywhere.

Agglomerate: to heap up, join, to gather into a mass: cluster

Agglomeration is further defined by the various techniques implemented. William Engelleitner, a long-time industry expert, presented an excellent paper entitled, "Agglomeration of Dusts - the effect of Agglomeration on Materials Handling and Bulk Transportation of Fine Materials" at the 7th Annual Bulk Materials Handling Seminar. Engelleitner listed the following fourteen agglomeration techniques:

1. Pelletizing

Rolling fines into a pellet or a ball, in the presence of moisture, either in an inclined disc, a drum or a cone-shaped device. Usually refers to minerals agglomeration.

2. Balling

Same as pelletizing; in a narrower sense means "green- balling" or producing a moist ball as opposed to the complete process of balling
and heat treating. {Note: this term is used extensively on the iron range for pelletizing. For the purpose of this paper, pelletizing and balling will be used synonymously.}

3. Micropelletizing

Producing very small, tiny agglomerates or irregular pellets without a high degree of compaction, such as in dust collector fines agglomeration. {Note: In several industries producing the highest quality pellets in mesh sizes up to 50 mesh is micro-pelletizing. This may also be accomplished to varying degrees in some of the mixing equipment but is best accomplished in the pin mills or pelletizing equipment.}

4. Conditioning

A fluffing, tumbling and wetting action with some degree of agglomeration, but no pelletizing. {Note: This can be accomplished in several types of equipment: mixers, blenders, pug mills, pin mills (mixers), mullers or pelletizing equipment.}

5. Instantizing

An expression used primarily in the food industry to describe the agglomeration of powdered food base materials by mechanical and chemical means.

6. Briquetting

The process of shaping fine materials into briquettes of pillow, droplet or almond shape, usually in a continuous double-roll press.

7. Compaction

The process of force compressing fines between two smooth rolls to produce a sheet, which is then typically broken into flakes, or compacts.

8. Tabletting

The process of producing wafers or spheres in continuous tablet presses by filling a die and stamping out the preforms. Usually limited to pharmaceuticals, powder metals, and ceramics.

9. Extrusion

Forcing a mass of fines through augers and an orifice to produce a shaped, elongated agglomerate, cylinder, or rod. Used in ceramics,
animal feeds, and plastics, but also metal powders and metallic shapes.

10. Induration

The firing of pellets (greenballs), such as taconite ore concentrate. This is done on a grate, grate-kiln, or in a shaft furnace at temperatures above 2000º F.

11. Sintering

Heat-fusing of a mass of mixed ore fines into a cinder which becomes hard and slag-like at temperatures of 1,500º F and above.

12. Nodulizing

Sometimes used to describe rolling of a mass into balls, or nodules, in a rotary kiln, such as for cement, ore concentrates, or refractories.

13. Granulating

Same as pelletizing, i.e., pellet forming, except that granulation usually refers to smaller pellets, such as fertilizers. (Drum Granulation - Pan Granulation) {Note: This is the fertilizer industries term for pelletizing or micropelletizing, generally 6 x 16 mesh. The equipment is normally drum or pan "granulators" (Pelletizers).}

14. Prilling

Forming of spherical agglomerates from hot melt concentrates, such as urea, ammonium nitrate, caustic soda or sulphur. The melt is sprayed from a shot tower against an updraft of cooling air, thus agglomerating into prills in suspension.

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The techniques of balling, pelletizing, micro-pelletizing, conditioning, and granulation are all accomplished as a general rule, most efficiently with the same equipment. That is not to say, however, that a specific material may not be best in the pin mill, which is frequently used for micropelletizing. In addition, conditioning, for some materials, may be best accomplished in the pug mill.

In general, however, the pelletizing equipment is used extensively in all five techniques by merely adjusting the available operational variables. There are four basic types of pelletizing devices; disc, cone, drum and deep disc.
Pelletizing results in a generally spherical shaped agglomerate, a pellet. Pelletization is caused by impacting a particular type of motion or agitation, normally rotation, tumbling and rolling to the powdered material during or subsequent to the addition and mixing with a liquid binder. All of the aforementioned pelletizing units produce the pellets in a somewhat similar manner.

Let’s take a look at what takes place in or on the machine and how the phenomena is achieved before explaining the difference in the types of pelletizing units.

Assume as a base condition; finely divided inert material with a distribution of particle size ranging from, say 40 mesh to minus one micron. Pure water will be the binding agent. The material need not be dry and indeed normally is not, but ideally, should have a few percent less moisture than the final pellet moisture for operational control. The material is fed to the unit at a steady controlled rate and the water is sprayed onto the material in the unit while the unit is rotating. Droplets of the water will collect several particles; the rotation will force impact and densify this loosely formed nuclei or seed. This densification forces water to the surface to pick up more particles. Continuing rotation causes the seed to recycle through the spray area to be re-wetted to pick-up still more particles and so on. (See fig. 1). The water will have been forced rather firmly into the minute interstices and nearly each and every particle will be coated with water.

This arrangement of the particles is not unlike that of a good concrete mix where all the spaces, interstices, between the larger particles are filled with smaller particles and the interstices between these are filled with yet smaller particles and so on until the final interstices are filled with water. (See fig.1). Surface tension and the capillary forces of the water is the major binding force that is holding the pellet together. There is a very thin layer of water between each particle, and this results in the pendular bonding system so ably described by the late Professor Rumpf. (See fig.2). Since we started with an inert material and pure water, the bond is caused solely by the water, should you dry the pellet, i.e., drive off the water the pellet will, lose strength accordingly. In practice, of course, the feed material is not totally inert and most often being made up of several materials, some of which in the presence of water will dissolve at least to a small extent or will react with one or more constituents and excellent strength may result. Drying the pellet will solidify the bond increasing the strength. The liquid of course can be anything to enhance the bond, if it is compatible with the end product. Binding liquid can be tailored to cause binding reactions or merely contribute adhesiveness. Inert relatively
course material or materials of a very narrow particle range would necessarily depend entirely on the adhesiveness of the binder.

![Figure 1](image1.png) ![Figure 2](image2.png)

There are materials with irregular enough particle shape that interlocking of the particles may take place during agitation, thus developing a mechanical bond. These bonds are infrequently a major factor. However, fibrous materials that will interlock or entangle often contribute significantly to pellet strength or friability.

As previously stated, there are several different pelletizing machines commercially available; the disc, the cone, drum and the deep disc. There is great similarity in how the pellets are formed in each of the units. All of these units have a circular cross section normal to the axis of rotation. All of the units rotate, though the required speed of rotation varies from unit to unit and from size to size for the same type of unit.

The rotation will pull the material up the wall of the unit in the case of the drum and cone (See fig.3) and up the sides and bottom or back of the disc and deep disc. (See fig. 4).
The water is sprayed onto this moving surface of material. When the material reaches a height it is no longer pulled or carried and gravity will cause it to roll down across the upcoming material. As described previously, the water droplet has formed the nuclei of the pellet with several particles, as it rolls downwardly, it is compacted, forcing the water to the surface thus enabling more particles to be picked up. As the rotation continues, this nuclei or seed is rewetted as it passes through the spray area thus contacting loose feed material to pick up additional material thus growing until reaching the end of the unit or growing to a size that causes it to discharge. Speed and angle of these units is so adjusted to discharge a maximum of “on size” pellets. Size control for the drum and cone is normally accomplished with a closed cycle screening system where over size is crushed and returned to the pelletizer with the undersize. Disc installations very often produce a product “on size” or with under and over size within acceptable limits. However, when close product size is specified, a disc system requires screening and recycling of the product discharge also. Feed material to the disc, drum and cone units have traditionally been wet, especially in iron ore pelletizing. The ore moisture content being at or just short of pellet moisture because feed preparation is a wet process. Dry pellet feed shows some advantages in certain situations and is often mandated by process. There has been very little theoretical work concluded for this application.

Alteration of what has been standard pelletizer geometry to gain a deeper bed of contained material in the pelletizer shows some indication of increasing dry feed productivity and can help minimize “dusting.” Dry feed is very often pre-conditioned prior to pelletizing in a standard circuit.
Feed material preparation is quite critical to successful pelletizing. Proper premixing of feed when there is a multiplicity of materials and especially if these materials are of different particle size range and or bulk density is also very important. To the extent possible mixing and handling immediately prior to feeding onto the pelletizer should also de-aerate the material and stabilize the feed bulk density.

Feed material particle size distribution is very important, as explained previously and especially to the drum and cone, and to a lesser extent the disc. The top size, (i.e., largest fraction) is critical and limited in all units. It is my experience that top particle size appears to be a function of material depth in the nucleation area of the unit but let's leave that study for a later time.

The pelletizing drum is used frequently in the high tonnage applications such as iron ore pelletizing. The drum has been also used quite frequently in fertilizer applications and equipped with special "internals" in detergent manufacture. The cone has not been nearly as popular. The disc has had the most wide spread acceptance throughout the broadest range of industries. The wide range of unit sizes and the fact that the geometry of the disc units has a natural tendency to classify thus making control somewhat easier, makes them an ideal solution for various materials. The deep discs, that is, units with depth/diameter ratio of .5 or greater, appear to have a higher tolerance for a higher percentage of coarse material. This advantage, however, is offset by the difficulty with the deep units to make the smaller size pellets.

Pelletizing units are universally sensitive to fluctuations in the feed, i.e., bulk density, particle size distribution temperature and feed rate (gravimetric) variation. In fact, maintenance of pelletizing rate and product quality is close to impossible without optimizing the constancy of feed rate. One needs but little experience in troubleshooting pelletizing systems to realize that making constant the material feed rate is the source of most pelletizer system problems. Experience has proven that inconsistent pelletizer feed rate is the most frequent source of trouble in maintaining constant and consistent pellet quality and obviously production rates.

Pellet size is often critical especially if the pellet is the end form of the product. Size may be just as critical however, when the pellet is an intermediate processing step. Maintaining constant pellet diameter throughout the length of the production run is not easy; it should be expected that periodic adjustments will be made. To achieve a pellet production of a given pellet size means "tuning" the available variables. The nature of the feed material itself dictates these adjustments. The
adjustments are: material feed rate, water feed rate, spray nozzle size and location, machine angle, and speed. Retention time in a machine is a function of machine angle and machine speed and feed rate. Material feed rate has narrow limits when maintaining close control over product size and quality and is dictated by machine size and geometry. Water rate also has narrow limits dictated either by the nature of the material or subsequent drying or process requirement. Machine angle and speed adjustment are largely dictated by machine geometry, “fine tuning” of speed and angle is gained through operator experience with the material being pelletized. This kind of experience and the ability to see subtle changes taking place in or on the machine give credence to the “art” involved in pelletizing.

The different units have different operating characteristics, some obvious and diverse, others but nuances. All operating differences and variables, however, are very dependent on the nature of “idiosyncrasy” of the material being agglomerated.

It is obvious that binder characteristics will add requirements and considerations of their own. It is not practical to go into operational detail here that is best left for in situ circumstances. It is also true that when working with particulate materials, the only practical general rule is that general rules are totally unreliable.

Pellet physical quality is quite obviously as critical as production rate and size control. Achieving physical quality involves some of the same adjustments to achieve and control pellet size. Adjusting retention time to alter reroll time for formed pellets has the greatest influence of pellet quality of all the machine adjustments. Changing chemistry (i.e., the use of stronger binders) of course would have the most profound effect on pellet quality. Unfortunately, this also increases the product cost. Adjusting feed particle size when practical or possible is often the surest way to achieve the desired quality at maximum production rates.

Pellet quality is first measured on the "green ball" or fresh pellet in terms of crush strength, number of drops preceding breakage from a measured height, and a tumble or abrasion index. These tests are often repeated after a given time of natural or ambient drying or specified time and temperature forced drying. There are tests dictated by the use to which the pellets are put, such as, determination of pellet abrasion resistance, porosity, and high temperature swelling. There may be others as required by special circumstances.

Care should be exercised when specifying pellet quality. For example,
specifying 60 pound crush strength when actually 10 pound crush is adequate can be specifying impractical costs or a parameter not possible for the material under consideration.

Though this paper has really been but an introduction, elementary and unsophisticated, a reference for general information, a starting place for further study, there is a wealth of more detailed information available.