Grinding for Aquatic Feeds

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Hammermills and Roller Mills for Aquaculture Feeds

Hammermills are commonly used for grinding a broad range of materials used in the production of aquaculture feeds. Since most species of fish, crustaceans, and shellfish have a very short digestive tract, they require a finely ground, highly processed feed in order to obtain good feed efficiency. Additionally, most immature and many adult specimens produced in the aquaculture industry have very small mouths, so a fine particle size is required simply to allow the animal to ingest the feed. Hammermills and air swept pulverizers are the two most common machines used to grind the materials to the fine particle size used in aquaculture feeds. Roller mills and crumblers are used to reduce the particle size of finished, extruded or pelletized feeds to make the specific size granules required for many species in various stages of development.

Hammermills vs. Air Swept Pulverizers Compared to most air swept pulverizers hammermills offer high efficiency, low heating, and reduced aspiration requirements. Maintenance costs for hammermills equipped with conventional hardfaced hammers and round hole screens are typically \$0.02-\$0.10/ton and electrical costs range from about \$0.25/ton, to more than \$1.00 per ton depending on the fineness of grind.

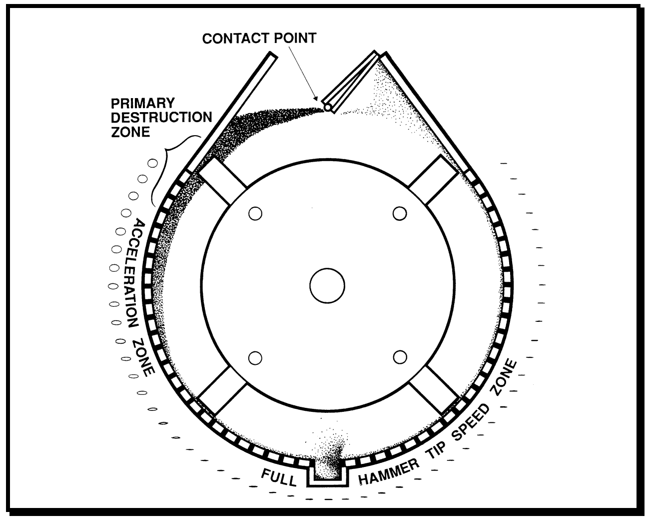
Because there is less heating of the product and lower air flow through a hammermill compared to an air swept pulverizer, materials ground through a hammermill will have less moisture loss than materials ground through air swept pulverizers. Typical moisture loss through a hammermill when fine grinding for aquaculture feeds is ½ to 2%. Hammermills are generally less expensive to install and operate than pulverizers, typically costing between \$250 and \$350 per HP for a complete system including the hammermill, feeder, and appropriate air assist system. Hammermills are somewhat limited in the finished particle size that can be conveniently achieved. Typical finished ground product from a conventional hammermill set up will be in the range of 95 to 99% less than 30 mesh (0.5 mm) with a mean particle diameter of 200µ to 300µ. Specially equipped hammermills are capable of grinding aquaculture rations as fine as 95 to 99% less than 60 mesh (0.25 mm) with a mean particle diameter of 100µ to 175µ. Air swept pulverizers with built in classifiers can recirculate oversize particles and achieve finished products in the range of 95 to 99% less than 100 mesh (0.15 mm) and a mean particle diameter between 40 and 75µ.

In many instances, “double grinding” systems are employed to obtain the fine finished products needed for efficient aquaculture feed production. Double grinding may be accomplished with a single hammermill, processing the entire batch through the hammermill then, perhaps with a screen change to improve the fineness of grind, rerunning the same batch back through the same hammermill. A second approach is to use two hammermills in series, grinding through a larger screen first (typically 1 to 3 mm) then regrinding the entire batch through a second hammermill with smaller screens (typically 0.4 to 1 mm). A third double grinding system uses a hammermill for the preliminary grind, and then through an air swept pulverizer for the finished particle sizing. Whatever the system may be, double grinding offers improved efficiency over single grinding operations with a finer, more uniform finished ground product.

Equipment Description

A hammermill consists of a rotor assembly with two or more rotor plates fixed to a main shaft, enclosed in some form of grinding chamber. The actual working mechanisms are the hammers and the screen or grinding plates that encircle the rotor. The hammers are simply flat metal bars with a hole at one or both ends and usually have some for of hardface treatment on the working end(s). The hammers may be fixed, fastened rigidly to the rotor assembly but much more common are swinging hammers where the hammers float on pins or rods. This swinging hammer design greatly facilitates changing hammers when the working edges are worn.

Reduction in a hammermill is primarily a result of impact between the rapidly moving hammers and the incoming material. There is some attrition of the particles (gradual reduction by friction) between the hammers and the screen and as the particles impact the internal components of the hammermill as they are being driven around the machine by the rapidly turning hammers.



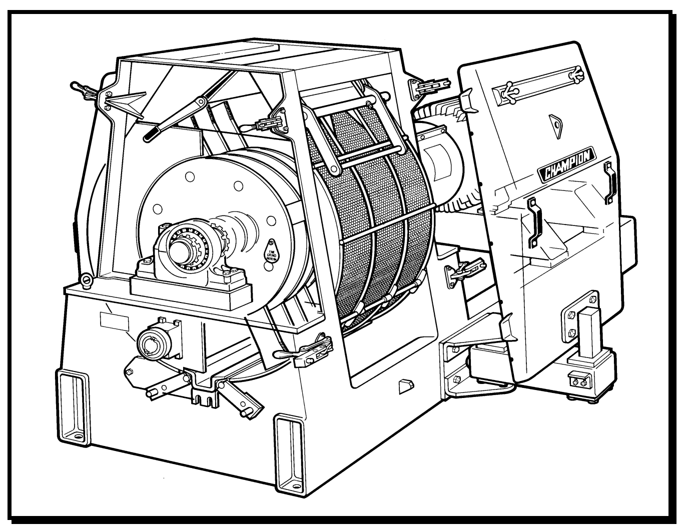
The efficiency of the grinding operation will depend on a number of variables including but not limited to: tip speed, screen (hole) size and open area, screen area / horsepower ratio, hammer pattern (number of hammers), hammer position (coarse or fine), uniform feed distribution, and air assist. In addition, the nature and quality of the material(s) being processed will affect the performance of the hammermill.

Basic Machine Characteristics

Hammermills used in aquaculture feed processing have many common characteristics. Here are a few basic design principles as they apply to maximizing the performance and minimizing the cost of operating a hammermill system.

Full Width Top Feed The modern hammermill design must include a full width top feed in order to achieve maximum efficiency and minimize the cost of operation. A full width feed insures the entire screen area can be used effectively, and that the work being accomplished will be evenly distributed across the full hammer pattern. The top feed permits the direction of rotation to be changed, allowing two corners of the hammer and both "edges" of the screen to be utilized before a physical change of the hammer is required.

Tear Shaped Grinding Chamber A tear shaped grinding chamber is necessary to prevent material from circulating within the grinding chamber. Most well designed modern hammermills have some sort of flow director in the top of the hammermill to properly feed incoming materials into the hammer path, and to stop any materials that are circulating within the grinding chamber.



Split Screen / Regrind Chamber Hammermill screens are commonly split in two pieces, with some device at the bottom of the mill to disrupt the flow of materials within the grinding chamber. The application of a split screen design will permit the user to adjust the screen sizing on the down side and up side to maximize productivity and product quality. A “Regrind Chamber” at the bottom of the mill introduces enough turbulence to swirl materials back into the hammer path at the 6:00 position. This regrind chamber must be large enough to take product out of rotation as the hammermill operates, but should not be so large as to reduce the available screen area significantly.

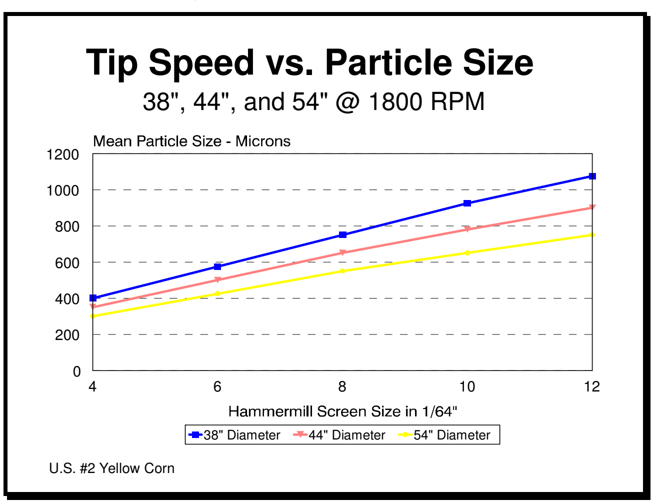
Robust Rotor Support In order to maintain the relative position of the rotor to the grinding chamber the foundation of the mill must be extremely robust. A solid, substantial structure positively maintains the clearances between the hammer tips and the screen through the full rotation for consistent, efficient processing. This stout design must be accomplished without sacrificing the accessibility to the grinding chamber, as routine maintenance of the hammers and screens will be required.

Replaceable Wear Items One final rule for a good hammer design is if it can wear, it should be replaceable. Beyond the hammers, screens, and pins, every component within the hammermill will be subject to wear. Accordingly, these components should be fabricated from wear resistant materials, heavy enough to provide good service life, and ultimately should be reasonably simple to replace.

Basic Operational Concepts

As noted, particle size reduction in a hammermill occurs as a result of the impact between a rapidly moving hammer and a relatively slow moving particle. The particle breaks and is accelerated towards the screen; depending on the particle size and angle of approach, it either passes through the screen or rebounds from the screen into the rapidly moving hammers again. As materials move through the grinding chamber they tend to approach hammer tip speed. Since reduction only occurs when a significant energy is transferred from the hammer to the particle (large difference in velocities), less grinding takes place as the particles approach full hammer tip speed.

While the basic operational concepts are the same for all hammermills, the actual operating conditions change rather dramatically depending on the materials being processed. Grains such as corn, wheat, and sorghum and various soft stocks like soybean meal tend to be quite friable and easy to grind. Fibrous, oily, or high moisture products like animal derived proteins and wheat bran are tough to grind and will require more energy to reduce. To achieve the best performance, the hammermill must be properly configured for the specific task of fine grinding for aquaculture feeds. The following discussion covers such factors as tip speeds, screen hole size, hammer patterns and position, horsepower ratios (to hammer and screen area), and air assist systems.



Tip Speed

Tip speed is simply a factor of mill diameter and motor RPM; ¶ D x RPM / 12 = TIP SPEED in Ft/Minute. Tip speed, in addition to screen size has a significant influence on finished particle sizing. High tip speeds (>20,000 Ft/Min) will always grind finer than lower tip speeds. Low tip speeds (<18,000 Ft/Min), on the other hand, produce a coarser, more uniform granulation with fewer fines. As a rule, smaller screen hole sizes should be used only with higher tip speeds, and larger screen hole sizes only with lower tip speeds.

Tip Speed - Fine Grinding and Tough to Grind Materials For fine grinding aquaculture feeds, a high tip speed is required. Normal tip speeds for fine grinding and fibrous materials are obtained on 44" diameter hammermills operating at 1800 RPM and 22" diameter hammermills operating at 3,600 RPM (20,700 Ft/Min), or 28" hammermills operating at 3000 RPM and 54" hammermills operating at 1500 RPM (21,000 Ft/Min). Recent developments in hammermill grinding have included the use of 54" diameter hammermills operating at 1800 RPM. This very high tip speed (>25,000 Ft/Min) is particularly well suited to fine grinding at high capacities and high efficiency. Because a larger screen (hole) sizes can be used while maintaining the fineness of the grind, operating costs are reduced as well. High tip speeds also help insure the hammers will not "rock" while the machine is operating with full motor loads, preventing excessive wear on the hammer holes and mounting pins.

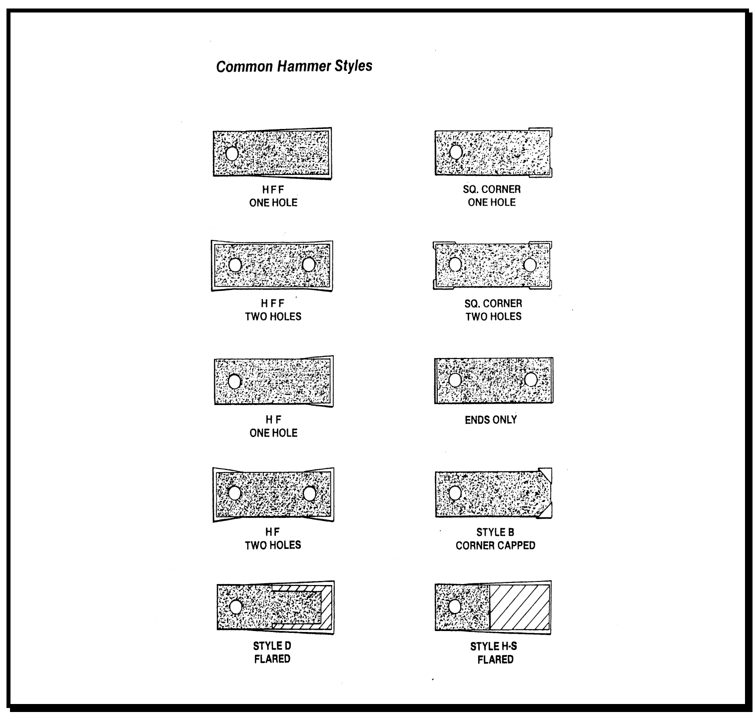
Tip Speed -Feet/Minute

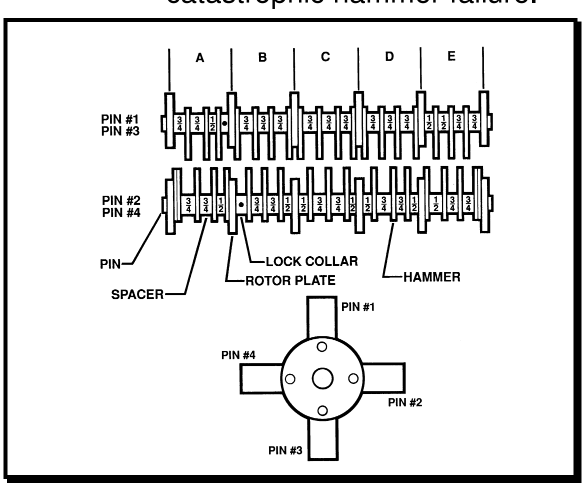
Rotor Diameter x RPM

Diameter	1200 RPM	1800 RPM	3600 RPM
19"	NA	7536	17898
22"	NA	10362	20724
28"	NA	13194	
38"	11938	17670	
42"	13194	19782	
44"	13823	20724	
54"	16964	25434	

Hammers

There are an unlimited number of hammer styles available from many suppliers around the world. At the same time, there are distinctly different types of hammers used in different regions of the world for a variety of hammermill grinding tasks. For longest hammer life and most efficient operation, a hammer with a flared hardface end (or ends) is preferred. Hammers may be one hole, with one working end (two corners) or two holed, with four corners available for grinding. One hole hammers are generally preferred to maintain balance of the rotor and minimize the potential for catastrophic hammer failure.





Hammer patterns (the number and distribution of the hammers on the rotor) and positions (setting the hammer closer to or further from the screen) have a profound effect on the performance of any hammermill. Because different materials grind differently, the ideal number of hammers and clearance to the screen will need to be adjusted according to each application.

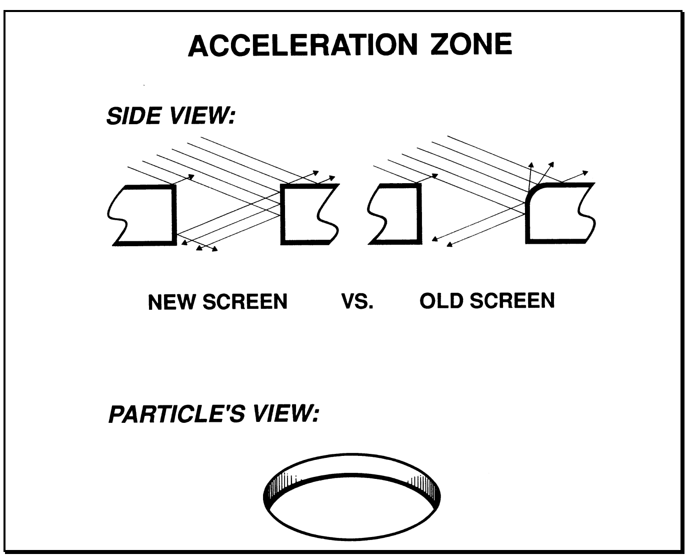
It is important to make sure the hammer pattern covers the working screen, without having hammers trailing hammers in line. In most cases, the hammer pattern should include double hammers on the outside rolls of at least two opposing pins. This is because the material in the grinding chamber near the sides of the mill moves more slowly than material in the middle of the mill due to friction on the sides, consequently the outside rows of hammers must do more work and are subject to more wear.

Most general application hammermills today are equipped with a rotor designed for a 4 pin hammer pattern or a 6 pin hammer pattern. Since the rotors are normally drilled for two hammer positions (coarse and fine) the rotors are actually fit with 8 or 12 sets of hammer pins. For aquaculture applications it is often necessary to use an extra heavy hammer pattern to achieve the very fine finished products desired: in many cases, the rotor will be equipped with hammers on all 8 or all 12 sets of hammer pins. This way the total number of hammers is increased significantly, without putting an excessive number of hammers on any individual pin(s), which could lead to high stress and the possible failure of the rotor plates. In addition to extra heavy hammer patterns, special “long” hammers may be selected to decrease the clearance between the hammer tip and the screen. This close hammer to screen clearance help push the fine, sometimes high oil aquaculture feed rations through the very fine hammermill screens.

Horsepower / Hammer Ratios

Hammer Size	Easy to Grind	Tough to Grind
6-8"	1 to 1.5 H.P./Hammer	.5 to 1 H.P./Hammer
8-10"	2.5 to 3.5 H.P./Hammer	1 to 2 H.P./Hammer

To insure the motor can start a machine with a heavy hammer load an electronic soft start may be required.



Screens

In terms of hammermill capacity and efficiency, the best screen for any job is the thinnest material with the most open area. Naturally, some sacrifice in efficiency must be made for the sake of endurance, yet the general rule applies. On the other hand, for many aquaculture applications there is a benefit to using screens with limited open area to promote a finer finished product. Indeed, many hammermills grinding in aquaculture applications are equipped with extended wear liners at the inlet of the machine to increase the impact and grinding that occurs when the product is first struck by the hammers. Some users go so far as to “blank off” a portion of the down side screen by placing a solid sheet metal plate behind the screen to prevent material from passing through the screen openings. This promotes finer finished products, although the production rate will be negatively impacted.

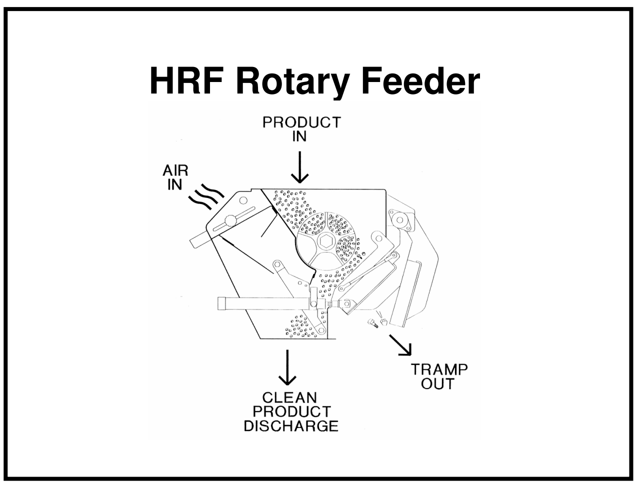
Factors effecting open area include hole size, stagger, angle of stagger, and hole spacing.   There are a few specialty screens being used in aquaculture applications to improve the grinding performance. One type of screen material is known as the "Conidur" with the holes punched is such a way that the surface is upset, almost like small louvers or the surface of a cheese grater. This type of screen can work effectively, but is very expensive to purchase and will reduce the machine capacity. One reason the "Conidur" type screen produces a finer finished product is the fact the open area is very low when compared to a conventional round hole screen with a similar opening diameter.

Sealing at the edges of the screen is particularly important when fine grinding for aquaculture feeds. The fit of the screen carriage and the wear liner must be precise to prevent any oversize particles from bypassing around the edges of the screen. At the same time, the screen must be adequately supported, as fine screens do not have the mechanical strength of thicker, heavier screen material. Regular inspections of the screens must be made to monitor the condition of the screens and to catch any worn or failing screens before they fail completely.

Feeders

Proper feeding of a hammermill is absolutely essential if the system is to operate at maximum grinding efficiency, and with the lowest possible cost per ton. Uneven or inconsistent feeding can lead to surges in the motor load. Because the load is constantly changing, the motor cannot operate at peak efficiency and so increases the grinding costs. An additional liability that is often "hidden" is the fact that surges in the feed may tend to accelerate wear on the hammers and pins by causing the hammers to "rock" on the pin.

Uneven feeding across the face of the hammermill obviously increases the wear on the working components in the areas of heaviest feeding. Because a part of the mill is being overworked, the rest of the mill is not being fully loaded and grinding efficiency is reduced. Uneven feeding also tends to cause a hammermill to go out of balance more quickly due to uneven wear. This adds to the operating cost of the mill by causing premature replacement of the wear items like hammer and pins.

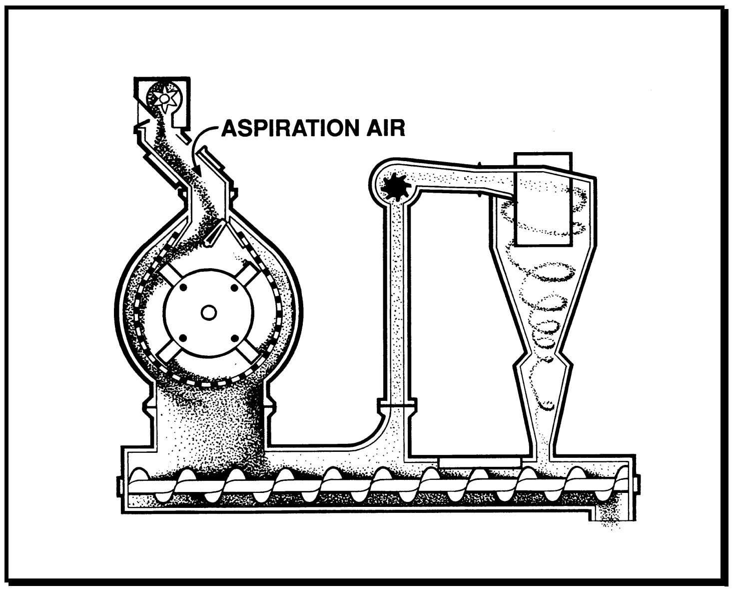


Rotary Pocket Feeder As the name indicates, rotary pocket feeders utilize a rotor mechanism much like a rotary air lock to evenly distribute the feed to the hammermill. In most cases, the rotor is segmented and the pockets are staggered to improve the distribution of the feed, and to reduce surges in the feed rate. Because the rotary pocket type feeders relies on a free flowing material to fill the pockets, they are best suited to granular materials with a density of 30#/Ft3 or more. Typical applications would be whole grains and coarsely ground mixed rations.

Screw Feeder Screw type feeders are used when processing materials that have poor flow characteristics, or contain large bits of material that would not flow properly with a rotary pocket feeder. Screw feeders may impart a surge to the feed, and so have limited applications in high capacity / high efficiency grinding situations. A properly designed screw feeder with multiple screws and double flighting at the discharge end will overcome many of the negative tendencies of screw feeders.

Air Assist

The final application topic to be considered is the use of aspiration air to improve mill efficiency and performance. The air assist system controls the environment of the grinding chamber in the hammermill and aids in moving product from the grinding chamber through the screen perforations. A properly designed air assist allows a hammermill to grind more efficiently, producing a more uniform finished product with less heating and controls dusting around the mill. Although hammermill capacity will vary with the type of machine and operational parameters, air assisted grinding systems will out produce non-assisted systems by 15-40%.



A good rule of thumb for the amount of air required to assist product and control dusting is 1.25-1.50 CFM/In2 of screen area. Pressure drop across the mill may range from 2-5" W.C., depending on system operating conditions. In order to make an air assist system work, several items must be considered including the air flow into the mill, paths for the air and product out of the mill, separating the product from the air stream, and controlling the path of the air in the system.

Once the air is through the mill, it is necessary to allow the entrained fines to settle out before sending it along to the cyclone or filter system. To accomplish this, a plenum or settling chamber should be provided between the air/product conveyor and the pickup point. The plenum must be designed to reduce the velocity as much as possible to permit the fine material to settle out, and with the air pick up point away from any swirling, turbulent fines material. If the plenum is designed so the air velocity drops below 15 times the bulk density (15 x 35 or 525 Ft/Min for most feed ingredients) the separation will usually be adequate. Larger plenums will reduce the velocity and improve the air/fines separation. For practical purposes, the plenum cannot be too large.

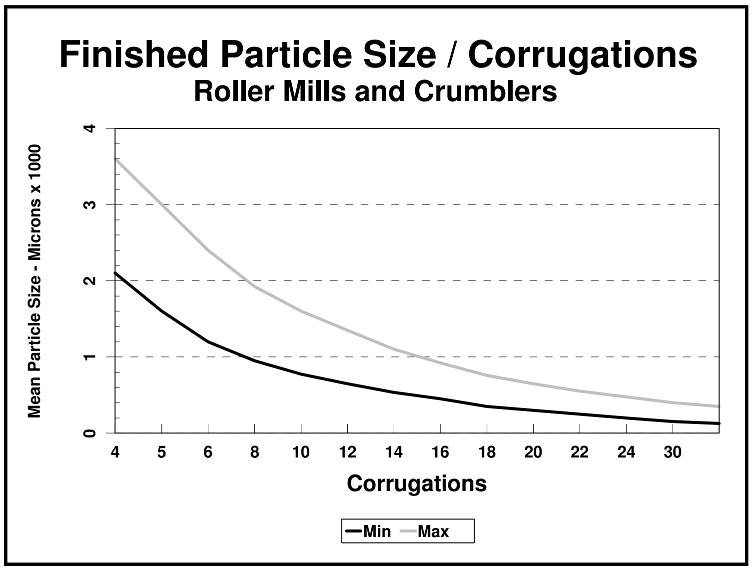
To make the air assist system work, it is necessary to control the path the air takes through the mill. Normally, the discharge end of the take away conveyor must include some kind of air seal to insure the air is pulled through the hammermill instead of back through the discharge system. This may be as simple as a shroud over the take away screw or as complex as a powered rotary airlock at the discharge of a drag conveyor.

Other Considerations

Magnetic protection is necessary in order to realize the best life of the working components of the mill. Tramp iron that enters a hammermill can knock holes in the screen, break hammers, and create undesirable sources of ignition. Mills that routinely operate with excessively worn or failed hammers will vibrate badly and promote bearing failures. The vibration monitor switch on a hammermill is intended to be used as an emergency shut down measure in case of a failure within the hammermill.

Always buy the best possible magnetic protection that is reasonable for a specific system and make sure the magnets are routinely cleaned. Magnets are relatively cheap insurance against damage due to foreign objects, but must be cleaned regularly to insure they continue to operate at maximum performance levels.

Roller Mills and Crumblers In the aquaculture feed industry, roller mills and crumblers are used to reduce the particle size of finished pellets or extruded products to a very specific particle size (range). Conventional pellet crumblers are single pair roller mills that can reduce the size of finished pellets by a factor of 4:1 up to about 10:1; the greater the reduction ratio, the broader the range of finished particle sizes. For greater flexibility, better particle size control, and finer finished products both double pair (two pair high) and triple pair (three pair high) roller mills are used to granulate pellets and extruded products. These machines employ progressively finer corrugations on the rolls to gradually reduce the particle size, while minimizing the production of undesirable fines and dust.



For extruded feeds, the top pair of rolls may require corrugations as coarse as 5 or 6 corrugations (grooves) per inch. Finer roll corrugations are used to produce finer finished products, with finished sizing of 85% <30 mesh (590µ) possible. Rolls will normally be equipped with a roll speed differential to create a shearing / cutting action between the rolls, resulting in a more uniform finished product.