

FLUID ENERGY MILL

Fluid energy mill is also known as pulverizers. It is used for fine grinding and close particle size control. The reduction of the particles takes place by the attrition and impact mechanism by the introduction of the air or inert gas through the nozzles.

The fluid energy mill mainly used to grind the sensitive materials to the fine powder by the mechanism of impact and attrition forces applied by the air or inert gas from the nozzles presents in the chamber.

The main basic parts present in the fluidized energy mill are as follows

- The inlet by which the solid material is introduced into the chamber which is made of stainless steel.
- The nozzles by which the air and the inert gas is introduced into the chamber at high pressure.
- The classifier from which the fine reduced particles are collected.

It consists of a loop of pipe which has a diameter of 20 to 200 mm, depending on the overall height of the loop, which may be up to about 2 m. There is an inlet for the feed and a series of nozzles for the inlet of air or an inert gas. It also has an outlet with a classifier which allows the air to escape but prevents to pass until they become sufficiently fine.

Principle

It works mainly on the principle of attrition and impact.

Working

In the operation of a fluid energy mill, gas of high energy content is introduced into a pulverizing chamber. The air or inert gas is introduced with a very high pressure through the nozzle. Solids are introduced into air stream through the inlet. Due to the high degree of turbulence, impact and attritional forces occurs between the particles. The fine particles are collected through a classifier. Fluid energy mill reduce the particles to 1 to 20 micron. To get a very fine powder even up to 5 micron the material is pretreated to reduce the particle size to the order of 100 mesh and then passed through fluid energy mill. A size-reduction unit depending for its action on collisions between the particles, the energy being supplied by a compressed fluid, (e.g., air or steam) that enters the grinding chamber at high speed. Such mills will give a product of 5 micron or less.

Fluid-energy mills, also known as jet mills, rely on collisions in a stream of particles entrained in a high-velocity fluid, typically air or steam, to effect breakage. In the “pancake” type, the particle-laden stream is injected through peripheral jets into a flat, cylindrical chamber at extremely high velocity. The highly turbulent environment so generated leads to high-velocity impacts between particles and with the walls of the chamber. The systems are generally designed so as to remove fine particles with the fluid while coarser material is retained for further breakage. An alternative arrangement is the opposed jet type in which particles enter the chamber through jets arranged in direct opposition to each other, the idea being to promote breakage by particle–particle collisions rather than by impact against chamber walls. Designs of this kind are intended to reduce contamination due to wear of machine surfaces. Fluid-energy mills are commonly used to produce particles in the 1–10 μm size range. Product size distributions are often relatively narrow which may be due in part to the loss of extremely fine (submicron) material in the product collection system.

As stated above, it is also known as the jet mill. Wikipedia defines it as a tool that grinds materials by using a high-speed jet of compressed air or inert gas to impact particles into each other. Jet mills can be designed to output particles below a certain size while continuing to mill particles above that size, resulting in a narrow size distribution of the resulting product. Particles leaving the mill can be separated from the gas stream by cyclonic separation.

Applications

- Pulverizers are commonly used for chemicals, pigments and food processing.
- The micro scale air impact pulverizer is used in laboratories, where small samples are needed. Fluid energy mills are used because of their advantages in fine grinding.
- The mill is used to grind heat sensitive material to fine powder.

- They have been used for the fine grinding of frits, kaolin, zircon, titanium and calcium, alumina, but the energy consumed per ton of milled product is high. It is also an object to provide grinding of dry solids.
- The mill is used to grind those drugs in which high degree of purity is required.

Particle size

A jet mill consists of a short cylinder, meaning the cylinder's height is less than its diameter. Compressed gas is forced into the mill through nozzles tangent to the cylinder wall, creating a vortex. The gas leaves the mill through a tube along the axis of the cylinder. Solid particles in the mill are subject to two competing forces:

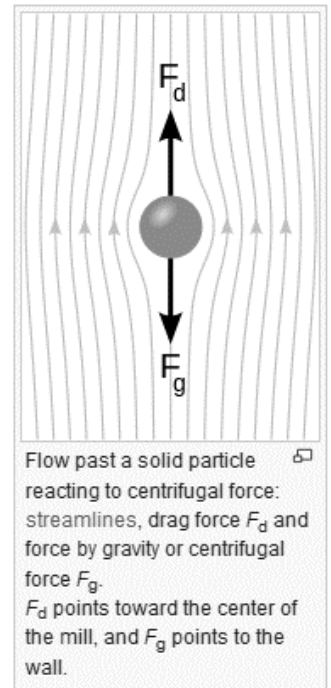
1. Centrifugal force created by the particles traveling in circles
2. Centripetal force created by the drag from the gas as it flows from the nozzles along the wall to the outlet in the center of the mill

The drag on small particles is less than large particles, according to the formula derived from Stokes' law,

$$V = \frac{2}{9} \frac{(\rho_p - \rho_f)}{\mu} g R^2,$$

where V is the flow settling velocity (m/s) (vertically downwards if $\rho_p > \rho_f$, upwards if $\rho_p < \rho_f$), g is the gravitational acceleration (m/s^2), ρ_p is the mass density of the particles (kg/m^3), ρ_f is the mass density of the fluid (kg/m^3), μ is the dynamic viscosity ($kg/m*s$), and R is the radius of the spherical particle (m).

The formula shows that particles will be pulled toward the wall of the mill according to the square of their radius or diameter. Large particles will continue the comminution process, until they are small enough to stay in the center of the mill where the discharge port is located.



Typical parameters

- Diameter of mill: from 0.05 meters to 1 meter (from 2 inches to 42 inches)
- Gas pressure: 8.3 Bar (120 PSI)
- Starting particle size: 800 microns or less, or as limited by the size of the inlet of the feed venturi
- Final particle size: down to 0.5 microns

Angle of Nip for a roll crushers

Particle just caught hold between the two rolls.

Angle of nip is the angle between the two roll faces at the level where they just take hold of the particle and draw into the crushing zone.

Let the radius of the roll and particle be 'R' and 'r' .

Let '2d' be the gap or clearance between two rolls.

Let the line AB pass through the centre of the L.H.E and the particle through point C. which is the point of contact between the particle and roll. It makes an angle ' α ' horizontal a tangent 'OE' at point 'C' makes the same angle ' α ' with the vertical.

Neglecting gravitational force two forces acts at the point 'C'.

1) F_r is the radial frictional force having vertical component $F_r \sin \alpha$

2) The tangential frictional force, f_t having vertical component $f_t \cos \alpha$

f_t is related to f_r by coefficient of friction ' μ '

$$f_t = \mu' f_r$$

$f_r \sin \alpha$ Component pushes the particle outside the rolls .

$f_t \cos \alpha$ Component pulls the particle inside the rolls for crushing

The material said to be crushed when

$$\mu f_r \cos \alpha < f_r \sin \alpha \quad \text{or} \quad \mu' f_r \cos \alpha = f_r \sin \alpha$$

$\mu' = \tan \alpha$, α is $\frac{1}{2}$ the angle of nip between the rolls

$$\cos \alpha = \frac{OA}{AB} = \frac{R+d}{r+R}$$

All the relations should be used to estimate angle of nip ' α '. Largest product diameter in '2d'.

What are the advantages of jet mills?

Jet mills have several advantages that can make them attractive to companies:

- As mentioned, there is no moving part in the milling chamber, so it is reliable and not prone to risks of mechanical breakages or wear that could cause some pollution of the final product
- It allows a narrow particle size distribution (PSD)
- It allows to reach very fine particle size, possibly in the 1-10 microns range for some materials

What are the disadvantages of jet mills?

Due to its technology, based on the injection of a gas (typically air, or an inert gas like nitrogen, argon, however steam can also be used), jet mills have also some limitations to consider:

- High energy consumption to compress the gas. It means that jet mills are used mainly for special products at high added value, for which the process becomes competitive
- Need to have a separation system integrated to recover the product from the gas used to perform the milling: brings additional costs and requires more footprint

How does a jet mill work?

High velocity impact

The principle of size reduction applied in a jet milling machine **is to have high velocity impact, in between the particles**, and in between the particles and the milling chamber. A gas (typically air, for air jet mills) injected at high speed provides the energy required for having many multiple high-speed impacts leading to a very strong comminution of the feed particles.

Grinding gas

The gas used in jet mill is usually one of the following:

- **Air:** the most common and most available gas, although not the cheapest as the compression work required requires a lot of energy. The pressure is typically 3.5-8.5 bar g
- **Steam:** actually, cheaper than air if the factory is equipped with efficient boilers. However, steam can only be used if it does not interact with the material (heat...). Typical pressures are 7-15 bar g with temperatures 200-520 c
- **Inert gases:** nitrogen or Argon can be used in some particular applications

Jet mills components

Suppliers are proposing 2 types of design:

- Fluidized bed jet mills
- Flat / circular jet mills without an air classifier

Fluidized bed jet mills

Those mills are equipped with vertical, cylindrical, milling chamber in which the material is introduced at the middle of the chamber, and the grinding gas injecting at the bottom. The air and product exhaust are from the top of the chamber; however, the outlet is equipped with a classifier allowing to select which particles, below a target size, can leave the mill, and which ones need to be recycled back to the milling chamber. As the gas is injected at the bottom of the chamber, the particles are fluidized with circulation streams establishing, hence the denomination of fluidized bed jet mill.

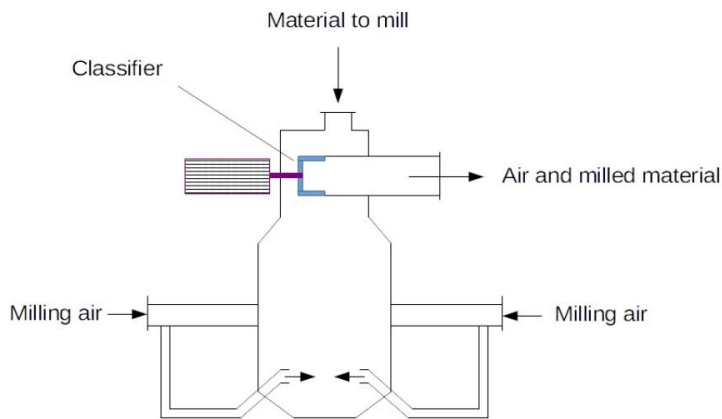
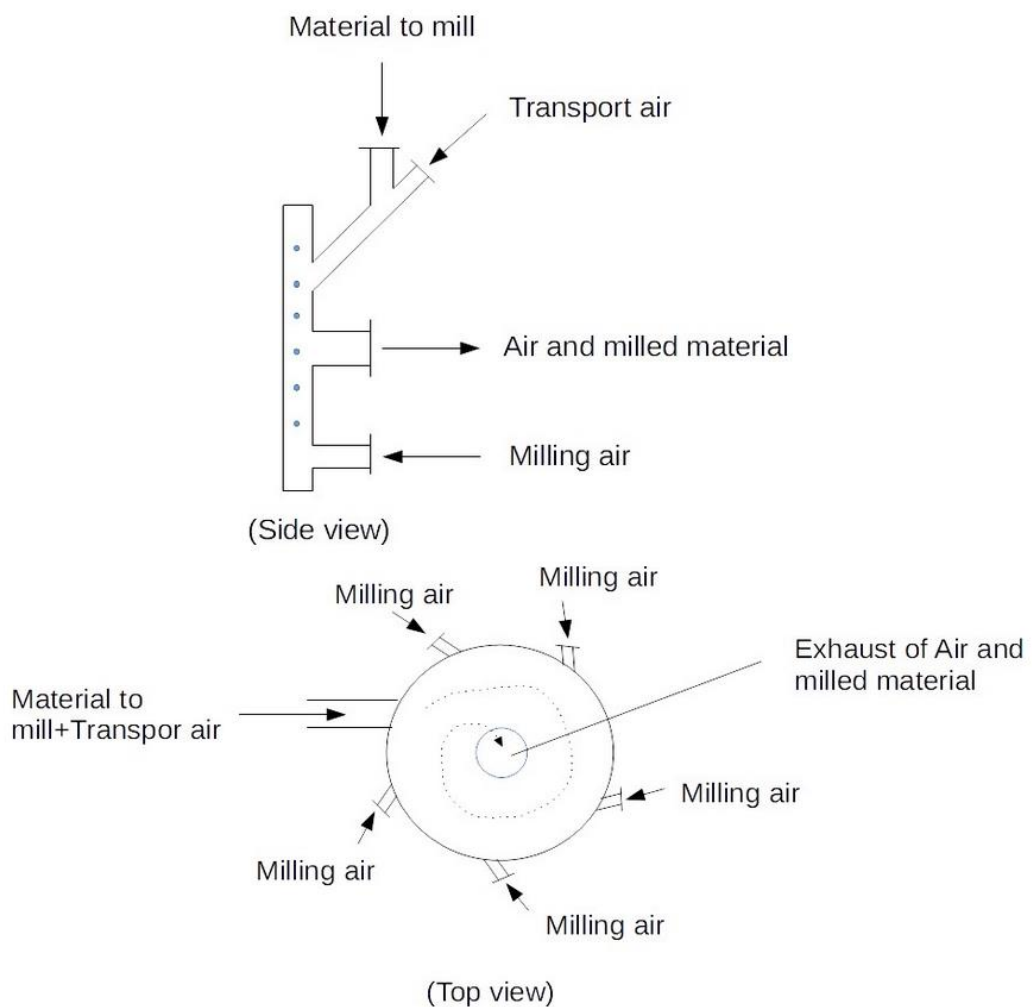


Figure 1 : Fluidized bed jet mill with classifier

Flat / circular jet mills without an air classifier

The other design is simpler, the material is fed into a grinding chamber similar to a disc where the gas is injected at several points. The air and the material milled is then exiting at the centre of the grinding chamber.



Feeding system

The feeding system to the milling chamber must act as an airlock in order to avoid that the air escape and prevent the inlet of material.

Gas - Solid separation

The milled particles are leaving the mill with a large volume of gas. It is then required to separate the material of interest, from the gas. It is typically done thanks to a cyclone, a filter or a combination of them.

Industrial jet milling machines

Jet mills can be designed up from few kg / h, typically for R&D lab environment, up to 6 t/h. Even if it is possible to reach such high capacities, it appears that most jet mills have a size of few dozens to few hundreds kg/h as they are employed mainly for specific productions in pharma or in cosmetics. Very large jet mills also require a lot of energy to compress high quantities of gas, making their economical justification limited to very specific cases.

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