

FLUID ENERGY MILLING

This is a dry milling technique and represents one of the most efficient, scalable, and industrially popular size reduction techniques. The principal mode of particle reduction is via particle-to-particle collisions with a limited contribution from metal-to-product contact. One type of fluid energy mill, also called an air jet mill or air classifying mill, consists of a circular grinding chamber into which the drug material is fed. Air enters the grinding chamber at a high velocity through a number of jets on the periphery of the chamber. The orifices of the jets are aligned so as to affect rotation of the drug material about the center of the chamber. Comminution of the drug occurs primarily near the outlets of the jets via collisions between the drug particles. The drug particles exit the grinding chamber at its center through an outlet coupled to a receiving vessel. The geometry of the grinding chamber, the position of the outlet, and the alignment of the jets cause the drug particles to follow a spiral course within the chamber. The centrifugal action causes the larger particles to move toward the outer walls of the chamber and the finer particles to move toward the center and through the chamber outlet. Particle comminution for a given mill is a function of the feed rate and nozzle pressure. Increasing the nozzle pressure and decreasing the feed rate affect a greater extent of particle size reduction.

Fluid energy mills are capable of producing ultrafine particles in significant quantities. Particle sizes of milled product from 1 to 30 μm are readily obtained. Fluid energy mills are capable of output rates in the 10–100s of kg/h (McDonald, 1971).

Fluid energy milling has several attractive features from a pharmaceutical processing perspective as it forms an efficient, effective one-step grinding and classifying operation. Fluid energy mills are simple, straightforward designs with no moving parts, and can be readily taken apart for cleaning and sterilizing. The milling process does not introduce any contamination (media, lubricant, etc.) into product from the mill. There is no significant heat generation coupled with micronization process, which makes it more amenable for thermosensitive compounds. In addition, the milled product is discharged directly into a receiving vessel, avoiding handling procedures associated with harvesting of the product from the mill.

Currently, besides catering to the pharmaceutical industry, fluid energy milling is employed for size reduction of agricultural chemicals, carbon black, ceramics, cosmetics, pigments, precious metals, propellants, resins, and toner materials.

BALL MILLING

A ball mill consists of a cylindrical vessel with a port for adding and discharging drug materials and grinding media. The vessel is made to rotate about its principal axis causing the grinding media to move up with the vessel wall and cascade down. The cascading action of the grinding media affects particle size reduction via attrition, impact, and compression caused by the cascading effect. The milling operation can be carried out under dry conditions or wet conditions using suitable media. Typical operating parameters of a ball mill for ultrafine grinding are as follows:

Media charge: 50% of vessel volume

Material charge: 25% of vessel volume

Rotational speed: 50%–85% of critical speed

The critical speed is the speed at which the grinding media cease to cascade owing to the centrifugal force imparted by the rotating vessel. The critical speed can be estimated by employing the following relationship (Lantz, 1990):

$$\text{Critical speed (rpm)} = 54 \div \sqrt{r_{ft}} \quad (17.43)$$

where r_{ft} is the vessel diameter measured in feet.