$$E = \kappa_K \log \frac{d_i}{d_n} \tag{10.4}$$

where κ_K is Kick's constant of energy per unit mass, d_i is the initial particle diameter and d_n the new particle diameter.

Bond's theory states that the energy used in crack propagation is proportional to the new crack length produced, which is often related to the change in particle dimensions according to the following equation:

$$E = 2\kappa_B \left(\frac{1}{d_n} - \frac{1}{d_i} \right) \tag{10.5}$$

Here κ_B is known as Bond's work index and represents the variation in material properties and size reduction methods, with dimensions of energy per unit mass.

Walker proposed a generalized differential form of the energy–size relationship that can be shown to link the theories of Rittinger and Kick, and in some cases that of Bond:

$$\partial E = -\kappa_W \frac{\partial d}{d^n} \tag{10.6}$$

where κ_W is Walker's constant and d is a size function that can be characterized by an integrated mean size or by a weight function, n is an exponent. When n = 1 for particles defined by a weight function, integration of Walker's equation corresponds to a Kick-type theory, when n = 2 a Rittinger-type solution results and when n = 1.5 Bond's theory is given.

When designing a milling process for a given particle, the most appropriate energy relationship will be required in order to calculate energy consumptions. It has been considered that the most appropriate values for n are 1 for particles larger than 1 µm where Kick-type behaviour occurs, and 2 for Rittinger-type milling of smaller particles of less than 1 µm. The third value of n = 1.5 is the average of these two extremes and indicates a possible solution where neither Kick's nor Rittinger's theory is appropriate. Other workers have found that n cannot be assumed to be constant, but varies with particle size.

Influence of size reduction on size distribution

In Chapter 9, several different size distributions were discussed and some were based on either a normal or a log-normal distribution of particle sizes. During a size reduction process the particles of feed material will be broken down and particles in different size ranges undergo different amounts of breakage. This uneven milling leads to a change in the size distribution, which is superimposed on the general movement of the normal or log-normal curve towards smaller particle diameters. Changes in size distributions that occur as milling proceeds have been demonstrated experimentally and this showed that an initial normal particle size distribution was transformed through a size-reduced bimodal population into a much finer powder with a positively skewed, leptokurtic particle population (Fig. 10.2) as milling continued. The initial, approximately normal, size distribution was transformed into a size-reduced bimodal population through differences in the fracture behaviour of coarse and fine particles (Fig. 10.3). If milling is continued a

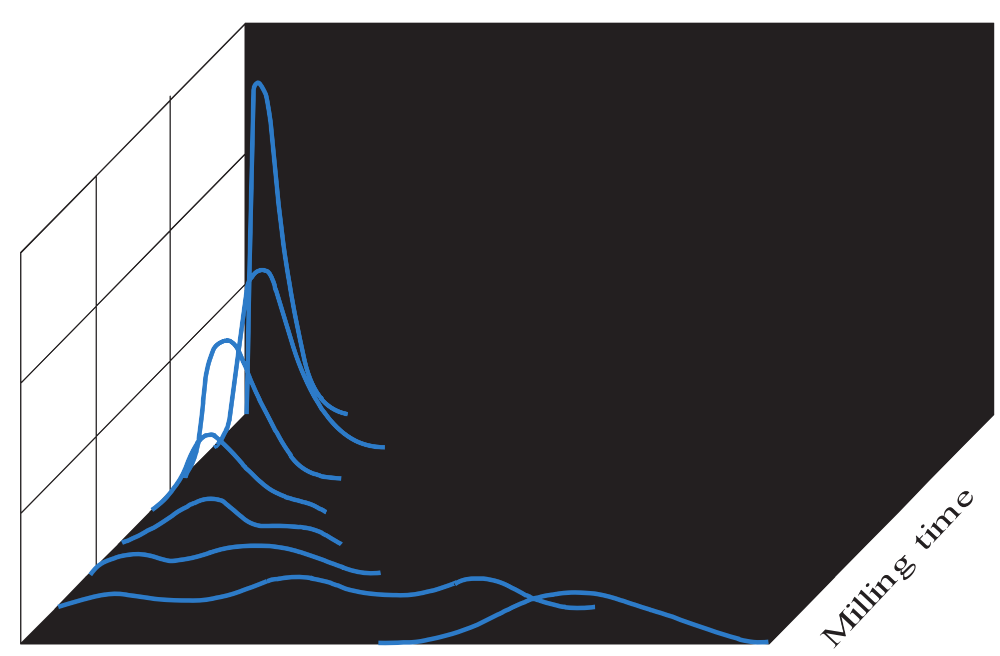

Fig. 10.2 • Changes in particle size distributions with increased milling time.

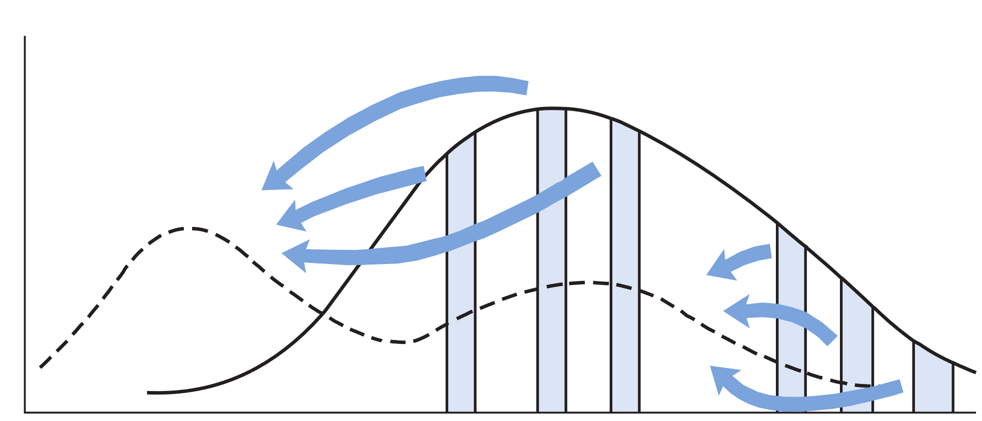

Fig. 10.3 • Transformation of approximate normal particle size distribution into finer bimodal population following milling.