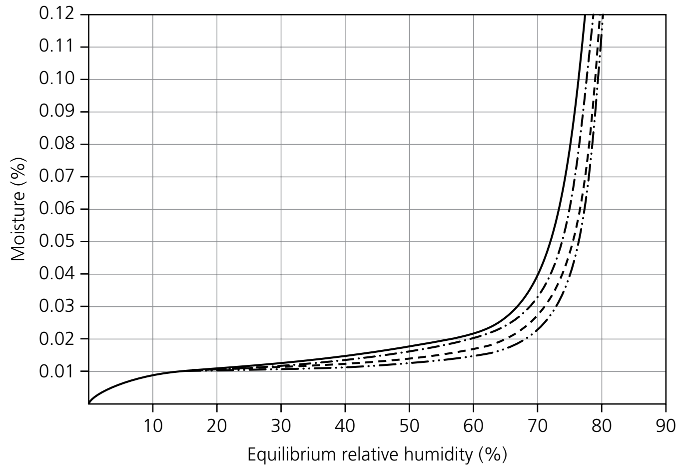

Figure 4.1 Sorption isotherms for crystallised sugars at 20 °C (68 °F; Kelm, 1983). Key: —, white sugar, fine, 0.0130% ash content; — · — · —, white sugar, coarse, 0.0135% ash content; ------, refined sugar, fine, 0.012% ash content; — · · — · · —, refined sugar, coarse, 0.0012% ash content.

According to 1972 EU sugar regulations, the water content in crystallised sugar, measured by loss on drying may reach a maximum of 0.06%.

External sugar silos should be equipped with adequate insulation as well as with heating elements in the silo walls to avoid the problem of condensation. However, some outdoor silos are constructed without insulation but the head-space in the silos is continuously filled with dried air, fed in through pipelines. Sometimes only the supporting case is heated.

The bulk density depends on crystal size and size distribution, but for a typical standard white granular sugar the maximum bulk density may be taken to be 850 kg/m^3 (53 lb/ft^3). When designing silo systems in practice, however, it is somewhat less and only reaches 750 kg/m^3 (47 lb/ft^3) during filling. At a surface moisture of 0.02–0.04%, the angle of repose of the sugar varies between 35 and 41°. The layout of sugar silos is often based on an angle of repose of 45–50°, with the discharge level in the tapered part being inclined at least 55° towards the horizontal. If the discharge angle is too small, proper discharge may be impeded. This may even lead to partial segregation, since larger crystals fall out more easily, whereas the smaller ones stick to the slip plane where they build up into a layer.

4.5 Sugar grinding and the prevention of sugar dust explosions

In contemporary chocolate production a two-stage refining process is normally used (see Chapter 9). This employs a two-roll pre-refiner to pre-grind granulated sugar together with other solid ingredients, which then become the feed

Table 4.3 Classification of sugar mills according to their operating mechanisms.

1. Mills with stress exerted by means of one solid surface or by the collision of two particles
   - **1.1.** Mills with rotating grinding devices
     - **1.1.1.** Mills with a grinding track
       - Hammer mill
       - Turbo mill
       - Impact pulveriser
     - **1.1.2.** Mills without a grinding track
       - Pin mill
   - **1.2.** Mills without moving mechanical parts
       - Air jet mills
2. Mills with stress exerted between two solid surfaces
       - Roll mill
       - Ball mill

material for a five-roll operation. More traditionally, in some chocolate factories the sugar is still pre-crushed to powdered or icing sugar, before being mixed with the cocoa mass, the milk powder and other ingredients and then roller refined in a single-stage process. Crystallised sugar is a brittle, medium-hard material. Its crushing during grinding takes place following fracturing processes, triggered by elastic tensions within the crystal. These fractures start propagating in the areas of minute structural flaws, which are always present in solid bodies. Since the frequency of such structural flaws is reduced with decreasing particle size, a higher energy input is required for the production of new interfaces when very fine sugar is required.

Three stress mechanisms are involved in the crushing of solid bodies by mechanical means (Rumpf, 1959):

- Compression crushing between two solid surfaces,
- Impact crushing by a solid surface or by particle–particle collisions,
- Using the surrounding medium to shear the material (i.e. solid surfaces are not involved).

Impact stressing is the most effective way of crushing sugar (Niedieck, 1971, 1972), and crushing by impacting with a single solid surface is the most common principle of present-day sugar mills. Table 4.3 shows a classification of sugar mills according to the type of breaking mechanism employed (Heidenreich and Huth, 1976).

Obtaining a closely defined particle spectrum during the grinding process is a major objective in the crushing of granulated sugar, because it results in improved flow properties of the chocolate mass produced. However, each mill will give its own particle size distribution in practice (see Chapter 9). For organoleptic reasons the maximum particle size should not exceed about 30 μm (1.2×10^{-3} in) in chocolate. On the other hand, 6 μm (0.5×10^{-3} in) is the minimum size, if optimum flow properties are to be achieved in the chocolate mass (Niedieck, 1971, 1972;