Better control of particle size distribution while reducing milling time is a goal all grinding operations strive to achieve. For a typical grinding operation, only 1 to 4 percent of the total energy consumed is actually causing particle breakage, while the remaining 96 to 99 percent results in collisions that don’t reduce the particle size, dissipates as heat, or is used for material handling. For small-scale or specialty grinding operations much of the cost of grinding is the labor and time for setup and cleanup, but for large-scale grinding operations, especially in the cement and mining sectors, energy consumption is the driving cost factor.

To maximize efficiency when grinding clinker, the limestone and aluminosilicate aggregates used to produce Portland cement powder, cement manufacturing operations typically combine multiple grinding processes such as roller mills and ball mills. This results in the grinding operation accounting for around 5 percent of the total energy required to manufacture cement. If you consider that millions of tons of cement are produced each year in the US, the importance of maximizing grinding efficiency is easy to see.

One way the cement industry has approached the challenge of maximizing energy efficiency during grinding is by using grinding aids. A grinding aid is typically a polar organic liquid, such as amine, glycol, or water, that’s added to a ball mill at a low level (less than 0.25 percent). This can increase the grinding rate by 20 to 100 percent compared to a system that doesn’t use a grinding aid. Many theories have been postulated to explain how grinding aids improve the grinding rate, including by enhancing crack propagation, enhancing the material flow characteristics in the mill, and minimizing agglomeration. While the mechanism is still being determined, it’s clear that grinding aids are improving grinding efficiency.

Despite this proven effect in cement manufacturing, grinding aids aren’t universally used in other industries. This may be because the optimal grinding aid must be determined for each material being milled or because manufacturers are hesitant to add foreign matter to a specialty grinding operation. However, the grinding rate and particle size distribution for a specialty grinding operation can be significantly improved by using a grinding aid.

In one specialty grinding application, for example, we were milling aluminosilicate ceramic in several 200-gallon ball mills with the goal of producing a median final particle size ($D_{50}$) of approximately 20 microns. To reach that goal, we’d optimized the ball mills by controlling the mills’ rotational speed, material load, and milling time. The mills were producing a usable final product, but we noted a significant cyclic variation in the product’s $D_{50}$ particle size as a function of production date, as shown in Figure 1.

After analyzing the materials and processing parameters, we determined that the processing...
room’s relative humidity, which was low in winter and high in summer, was the major factor affecting the particle size variation. By adding small amounts of water to the ball mills as a grinding aid, we were able to eliminate the cyclic variation and more accurately control the \(D_{50}\) particle size, as shown in Figure 2. While the intent was only to control particle size distribution, we found that the
grinding aid also reduced the required grinding time by more than 50 percent while maintaining the desired D_{50} particle size for the final product, as shown in Figure 3.

From my discussions with others in the field, grinding aids also appear to be beneficial when grinding glass, alumina, and other ceramics in ball mills and jet mills. The International Fine Particle Research Institute (IFPRI), a nonprofit consortium of companies interested in furthering particle science and technology, recently commissioned a review of the use of grinding aids to increase awareness and insight into this method of grinding optimization. With increased awareness, grinding aid use should become more widespread, resulting in improved products, increased energy efficiency, and the development of better models for particle breakage and comminution.

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Reference
1. For more information about the mills and milling processes discussed in this column, see previous “Milling Mentor” columns or articles listed under “Size reduction” in Powder and Bulk Engineering’s article index in this issue or in the Article Archive on PBE’s website, www.powderbulk.com. (All articles and columns listed in the archive are available for free download to registered users.)