Using hydraulic roll crushers and high-efficiency separators increases a dry grinding system's cost-effectiveness by improving system capacity and reducing power consumption. Read this article for information about using this equipment in various system arrangements to improve capacity and power efficiency.

Dry grinding systems are used for cement and other brittle solids with low elasticity and plasticity, such as limestone, shale (clay), sand, cement clinker (calcium silicates), slag (glass), and minor additives, such as iron ore. This article focuses on systems used for cement grinding, but the information can be applied to grinding any brittle solid with low elasticity and plasticity.

For years, these materials were ground with open-circuit ball mill systems, which didn't include separators. Later, to improve product quality and reduce power consumption, particularly with products finer than 3,200 cm²/g, closed-circuit ball mill systems with conventional separators were used.

Since 1985, with the drive for higher capacity and lower power consumption, new and existing dry grinding systems have commonly included hydraulic roll crushers (also called double-roll or twin-roll crushers) and high-efficiency separators. The hydraulic roll crushers have increased capacity between 25 percent and 120 percent and reduced power consumption between 10 percent and 40 percent. According to an independent survey of 19 North American installations with high-efficiency separators, on average, capacity has increased 26 percent and power consumption has decreased 14 percent.

Many dry grinding system arrangements have been used, all in an effort to make dry grinding more cost-effective. By using a hydraulic roll crusher and a high-efficiency separator in your dry grinding system, you may be able to improve capacity and reduce power consumption enough to justify the equipment's capital expense.

Because much information on high-efficiency separators has been published, this article focuses on using a hydraulic roll crusher in various dry grinding system arrangements. The hydraulic roll crusher (Figure 1) discussed here has two counter-rotating rolls loaded by hydraulic pressure. The rolls are smooth and are made from a high-grade forged steel alloy. In operation, brittle 30-millimeter particles are fed between the rolls and crushed to 3 millimeters in one pass. The material must be choke-fed so that the rolls are constantly full; this permits crushing both by the rolls and by particle-to-particle attrition, which produces a finer grind. Equipped with a hydraulic roll crusher, the dry grinding system consumes from 1.5 to 2.2 times less power than a closed-circuit ball mill system.

In the following information, which is based on several installed system arrangements, the hydraulic roll crushers typically handle cement (cement clinker and gypsum) and slag mixtures. Roll crusher capacity ranges from 100 to 600 t/h with from 800 to 2,000 kilowatts applied power per roll crusher. The system capacity ranges from 100 to 250 t/h. The return on investment in each installation depends on the user's needs either for higher capacity or for a specific reduction in power consumption.
System A

System A (Figure 2) consists of a hydraulic roll crusher, one (or more) feed bin, one (or more) double-chamber ball mill, a high-efficiency separator, a baghouse dust collector linked to an exhaust fan, and a pneumatic pump. In operation, material flows into the hydraulic roll crusher, which is run by a constant-speed motor or variable-speed motor drive to maintain a choke-feed condition. The roll crusher reduces the material and discharges it into the feed bin. The feed bin gravity-discharges the crushed material to the ball mill for further grinding in the mill’s first chamber, which has large milling balls for primary grinding, and then in the second chamber, which has smaller milling balls for finer grinding.

The ground material and dust-laden air pass from the ball mill to the high-efficiency separator, which recycles reject (oversize) particles back to the ball mill and passes properly sized material and fines to the dust collector. The dust collector removes the fines and exhausts the cleaned air while collecting the final product in a hopper that discharges by means of a screw feeder to the pneumatic pump. The pneumatic pump transports the product to a packaging or shipping area. Mechanical handling systems, such as belt conveyors, chutes, and elevators, move the material to the hydraulic roll crusher, feed bin, and ball mill; a pneumatic handling system (dashed lines on Figure 2) moves the dust-laden air from the ball mill, through the separator, to the dust collector.

This system is typically used when one hydraulic roll crusher must feed one or more ball mills. The roll crusher is located in front of the feed bin (or bins), because either the roll crusher won’t fit inside the building or this location is most convenient for feeding multiple ball mills.

System A typically achieves 30 percent more capacity and consumes 10 percent to 20 percent less power than a closed-circuit ball mill system. System A is commonly used to retrofit existing systems.

System B

System B (Figure 3) has the same equipment, but the hydraulic roll crusher is located after the feed bin (or bins), and there’s typically only one roll crusher per ball mill. In operation, material gravity-discharges from the feed bin (or bins) and enters the roll crusher, where it’s crushed. The crushed material flows to the ball mill, which grinds the material and passes the ground material and fines to the high-efficiency separator. The separator sends the rejects to either the roll crusher or the ball mill for further reduction and sends the properly sized materials and fines to the dust collector. The rest of the operation is like System A’s.
Locating System B's hydraulic roll crusher inside the building allows recycling the separator rejects to the roll crusher; this controls the feedrate to the roll crusher and ball mill while maintaining the roll crusher's choke-feed condition.

Like System A, this system typically achieves 30 percent more capacity than a closed-circuit ball mill system. Recycling ball mill rejects from the separator to the hydraulic roll crusher doesn't significantly reduce the system's power consumption, but the rejects help control the feedrate to the roll crusher and promote uniform flow through the rest of the system. Uniform flow is particularly important when producing different products at different finenesses, which can drastically change production rates. The reject quantity recycled by the separator normally equals 10 percent to 30 percent of the system's total production quantity. Recycling a greater percentage of rejects can lead to unstable roll crusher operation (such as erratic power consumption or vibration) because the fine material is difficult to deaerate between the rolls.

System B is used in retrofits and new systems.

**System C**

System C (Figure 4), often called a hybrid grinding system, includes the same equipment as System B, but has more mechanical handling equipment to handle additional recycling. In operation, two additional recycle streams — one for large roll-edge material and one for other roll discharge — are circulated through the hydraulic roll crusher before the material is further processed. Roll-edge material is large material that results because pressure across the roll face is typically unevenly distributed, so that more particle fracturing occurs at the roll's center than at the edges and larger, unfractured particles exit the roll edges. Recycling this roll-edge material and the roll discharge improves the roll crusher's overall effectiveness by improving product fineness, which minimizes large particles in the roll crusher discharge (which could limit the ball mill's efficiency) and large particles (survivors) in the final product.

Material recycled from the hydraulic roll crusher is coarser than that from the ball mill, so that larger quantities can be recycled by the roll crusher. However, the roll crusher's recycle rate shouldn't exceed 250 percent of the system's total production rate; otherwise, too many fine particles can enter the roll crusher and make its operation unstable.

System C's increased recycling can increase capacity from 30 percent to 80 percent over that of a closed-circuit ball mill system. However, improving capacity by recycling the roll crusher discharge, as in this system, involves some tradeoffs: The roll crusher's roll size and power must be commensurately larger, and the system requires more material handling equipment. But the system uses power more efficiently, and the higher capital investment for the larger roll crusher and additional handling equipment is still less than that required for a new closed-circuit ball mill system or the cost of maintaining an older, smaller closed-circuit ball mill system.

System C is typically applied to one ball mill in new systems or retrofits.

**System D**

System D (Figure 5) has equipment similar to that in Systems B and C, but includes a deagglomerator (typically a hammermill or horizontal impact crusher) located after the hydraulic roll
crusher. The system is used for raw materials or moist feed, such as slag, rather than cement grinding. In operation, the roll crusher discharge is further reduced in the deagglomerator, and the deagglomerator discharge passes to the high-efficiency separator, which recycles large particles to the roll crusher and separates the fines before the product goes to the ball mill. The system achieves 30 percent to 80 percent more capacity than a closed-circuit ball mill system and reduces power consumption by 20 percent to 30 percent.

By using hot waste gas (typically from a cement kiln's exhaust), the deagglomerator can also dry the feed material before it goes back to the hydraulic roll crusher without consuming additional power to heat the drying air. This permits the system to handle feed materials containing from 3 percent to 10 percent or more moisture. Though the deagglomerator increases the system's capital cost, the deagglomerator can also be integrated with the high-efficiency separator to reduce cost and space requirements.

System D is used for new systems and retrofits.

System E

System E (Figure 6) also uses a deagglomerator but has no ball mill. In operation, the deagglomerator's crushed discharge and fines (dashed line in Figure 6) pass to the high-efficiency separator, which recycles rejects to the hydraulic roll crusher while the fines and properly sized product pass to the dust collector.

The system can pregrind slag for use in mixture cements, but the lack of a ball mill normally limits the system's application to softer materials like burnt lime and cement raw meal (kiln feed). Without a ball mill, the system's power consumption can be 50 percent to 66 percent less than that of a closed-circuit ball mill system. However, the system requires high circulation ratios (feed-to-final-product ratios) and so needs a relatively large roll crusher, which has a higher capital cost.

The system has another limitation in finish grinding cement: Without a ball mill, the system doesn't generate enough process heat to properly calcinate the gypsum in ordinary cement. Without proper gypsum calcination, the cement particles remain too large and the system can't correct the particle size distribution to ensure the finished cement sets properly.

For applications with final product finenesses up to 3,200 cm²/g, this problem can be solved by modifying System E to feed an open-circuit ball mill (located after the high-efficiency separator). In operation, the combination of the hydraulic roller crusher and the high-efficiency separator produces a 1,500- to 2,500-cm²/g cement, called a semiproduct. The semiproduct goes from the separator to the ball mill for finishing, often called semifinish grinding, to produce cement as fine as 3,200 cm²/g. The ball mill can correct the cement's particle size distribution and its setting properties to make a salable product.

This semifinish grinding setup (modified System E) can maximize the hydraulic roller crusher's higher power efficiency (as long as enough ball milling occurs to maintain the cement's setting properties) because the high-efficiency separator returns a coarse, clean recycle — free of fines — to the roll crusher. This prevents deaeration of the roll crusher feed and resulting operation problems. In fact, when the roll crusher's power requirement is more than 40 percent of the ball mill's power requirement, the system arrangement must change from hybrid grinding (System C) to semifinish grinding (modified System E), so that the deagglomerator can separate the fines before any material recycles to the roll crusher.

The modified System E has a higher capital cost but consumes less power than System C — generally 20 percent to 30 percent less — by maximizing the hydraulic roller crusher's power efficiency. And unlike Systems A through D, which require double-chamber ball mills to prevent large particles from accumulating in the ball mill, the modified System E allows use of a single-chamber ball mill with optimum milling ball size, and the ball mill wears less because the ball mill feed is finer. The system can also increase capacity more than 100 percent over a closed-circuit ball mill system.

However, the modified System E isn't suitable for applications requiring cement finer than 3,200 cm²/g, such as high-quality, high-Blaine cement, because the open-circuit ball mill discharge doesn't pass through a high-efficiency separator, leaving some coarse particles in the product. This makes the system inherently inefficient for very fine products and reduces the system's power efficiency. Though adding a second high-efficiency separator to make the ball mill closed-circuit rather than open-circuit would permit the system to produce cement finer than 3,200 cm²/g, the system would then consume 8 percent to 10 percent more power and seriously degrade the hydraulic roller crusher's power savings, as well as increase the system's capital cost.

System E, either without the ball mill or modified to include one, is applied to new systems and retrofits.

Combining an integral deagglomerator with two high-efficiency separators

A recently developed unit (Figure 7) for the semifinish grinding process can prevent leaving coarse particles in the product, as occurs with the modified System E. The unit also maximizes the hy-
Currently installed after the roll crusher in a pilot plant grinding system, the unit uses two high-efficiency separators: a fines separator and a separator with an integral deagglomerator, called a deagglomerator/separator. The fines separator and the deagglomerator/separator improve the final cement quality rather than just remove fines from the roll crusher feed to prevent unstable roll crusher operation.

The unit's fines separator and deagglomerator/separator are located within the same housing and use the same process air, which reduces power consumption. The unit has two feed inlets: The bottom inlet feeds the hydraulic roll crusher discharge into the deagglomerator/separator for further crushing and for separating the coarse material. The top inlet feeds the ball mill discharge into the fines separator to remove fines. The deagglomerator/separator rejects the intermediate coarse material and recycles it to the ball mill, which allows use of a single-chamber ball mill with small milling balls for finer grinding. The fines created by the roll crusher pass through the deagglomerator/separator with the final product. Rejects from the deagglomerator/separator return to the roll crusher, so that only coarse material — rather than fine and coarse — feeds to the roll crusher.

Because the coarsest material recycles back to the hydraulic roll crusher, the material doesn't contact the separator rotors, which prevents rotor wear. The fines separator also handles the material at final fineness rather than at the coarser, more abrasive semifinish stage (1,500 to 2,500 cm²/g). The unit can help a grinding system produce material of any fineness. Using the unit in a finish grinding system with a hydraulic roll crusher is ideal for slag grinding. The unit can also be used as a dryer for materials with greater than 3 percent moisture by circulating a cement kiln's hot exhaust air through the unit. The unit's capital cost is comparable to that of System E.

Conclusion

As you can see in the progression from System A through System E, a dry grinding system that incorporates a hydraulic roll crusher and a high-efficiency separator achieves higher capacity and consumes less power than a closed-circuit ball mill system. However, the systems' capital costs increase as power consumption decreases.

To determine which system is suitable for your new or retrofit application and whether the system will provide a good return on investment, consider the cost of grinding power per kilowatt hour in your location. For a retrofit application, also consider how much space is available in your plant and whether the system's equipment arrangement will work with your plant layout.

Endnotes

1. Fineness measurement is particle surface area per unit mass.
2. Based on experience of Fuller Co., Bethlehem, Pa.

J. Mark Brugan is regional manager, cement division, at Fuller Company, 2040 Avenue C, Bethlehem, PA 18017-2188; 215/264-6011. He holds BS and MS degrees in ceramic engineering from Alfred University in Alfred, N.Y. This article is adapted from an article the author wrote for the September 1991 issue of Pit & Quarry.