

TERRASOURCE GLOBAL WHITE PAPER – *Unique characteristics of cage mills expand applicability across mining operations*

Smaller product sizing, reduced fines and lower maintenance frequency broaden application range for next-gen Cage-Paktor® cage mills

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It is no secret that most mining operations continue to look for more precision and less waste in their material sizing capabilities, as well as for solutions to meet the internal process requirements of many customers who are now demanding finer grind and smaller product sizes. These factors create an ongoing state of evaluating critical aspects of material sizing machinery, particularly in terms of how it can increase the expanded expectations of an operation's performance, efficiency and cost effectiveness.

As a result, crushing-equipment vendors must continue to find innovative ways to broaden their value proposition to customers, whether through new types of machines or strategic upgrades to existing

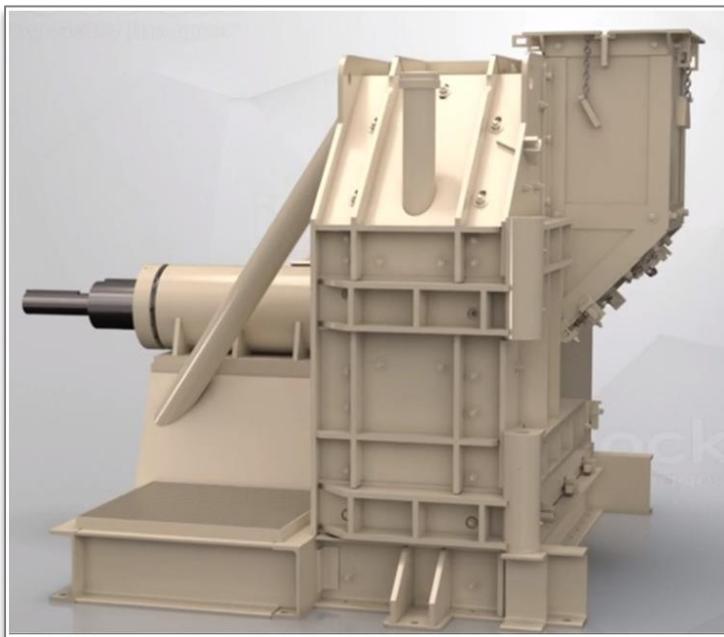


Figure 1 -- Exterior of Gundlach Cage-Paktor®

technology. For example, even though TerraSource Global is well-regarded in the industry for its full range of hammermills and [expansive array of roll crusher configurations](#), the company is now finding that the capabilities of its Gundlach Cage-Paktor® cage mills (Figure 1) have worked their way into conversations normally focused on machines such as ball mills, rod mills, vertical shaft impactors, roll grinding mills and hammermills.

Cage mills are already recognized as one of the most efficient and durable machines for precise, low-fines sizing of materials such as potash, lime, magnesite, bauxite, limestone, and coke. Many mining and material processing customers have assessed that not only are the capabilities of cage mills

much broader than previously realized for these materials, but these machines are also well suited to effectively handle additional applications such as refractories, waste byproducts, clays and other manufactured products. Cage mills can provide improved performance and efficiency as well in grinding, comminution, and beneficiation circuits by reducing the amount of work that must be completed by final sizing equipment.

Enhanced cage mill designs provide more value to mining operations

Even with all of these advantages offered by most types of cage mills, one of the most common themes that TerraSource engineers have received from customers beyond the need for expanded capabilities and enhanced performance is an absolute requirement for increased durability to extend mean-time-between-failure (MTBF) and improved mean-time-to-repair (MTTR) through better safety and ease of maintenance.

To meet these expectations, TerraSource engineers added design modifications, more configurations and new material compositions to the already advanced Cage-Paktor package. In order to understand the benefits of these machine enhancements, it's helpful to first examine the unique design of cage mills and understand some of the advantages they can offer over other types of crushing equipment.

Exploring the unique design of cage mills

In general, cage mills are screenless impact crushers that, rather than rolls or hammers, rely on rotating concentric steel cages to size materials. Feed enters the innermost cage and is initially struck by the first row of cage sleeves, which then scatter the shattered material outward toward the next row that rotates in the opposite direction (see Figure 2). More reduction occurs as the material moves outward through each successive row until the material exits the final row and is thrown against impact plates that line the crushing chamber.

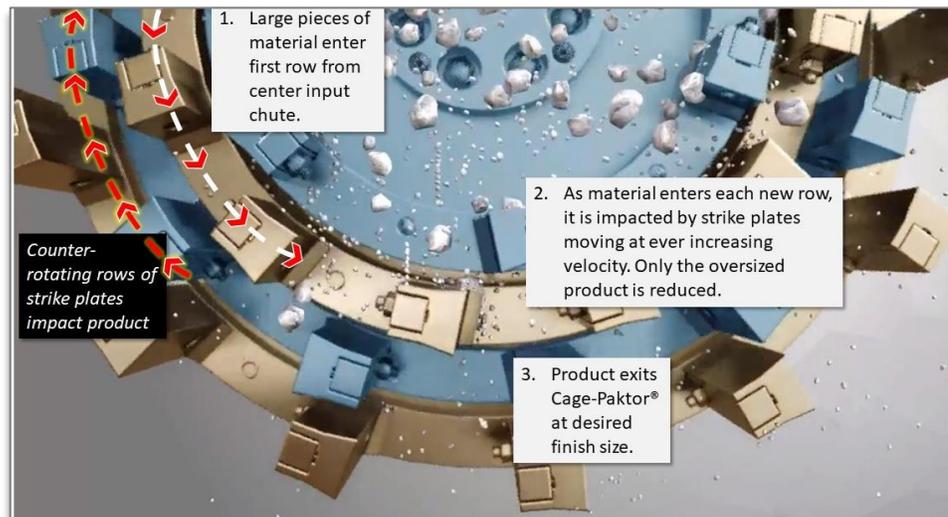


Figure 2 – Material processing flow through Cage-Paktor® cage

The sized material then discharges through the open bottom of the mill. This crushing process differs from typical solid rotor or hammer impactors that rely on minimal large impacts with a combination of stationary and moving impact surfaces with much less material flow control. In a cage mill, the speed of the cages is the primary factor for controlling output size, with the number of impact rows and the quantity of striking elements in each row also influencing the sizing outcome in a secondary capacity.

TerraSource engineers found that limiting variables allows for the most accurate machine performance; as such, ideal product flow and machine capacity is maintained by ensuring that the quantity of striking elements in each row for a given Cage-Paktor are consistent. These machines can easily achieve 40:1 reduction of feed material and vary from coarse to fine output. Multiple configurations are available with 1 - 2 independently moving cages, usually with 3 - 6 rows.

Cage mills are generally less expensive and offer a much smaller footprint than machines that can perform in a transition range between crushing and the comminution/grinding category. Cage mills can

far exceed the capacity of these traditional grinding and comminution types of equipment that require passing all the material through small holes or gaps that make up a relatively small area.

Performance benefits offered by cage mills

The unique design and capabilities of typical cage mills are not appropriate for some types of applications and should obviously not be considered a wholesale alternative to other material crushing solutions, like [roll crushers](#). However, in certain instances, cage mills, especially the enhanced Cage-Paktor, do offer considerable advantages over alternative crushing methods. These advantages include:

- **Less susceptibility to plugging**, especially for wet or sticky materials – Cage-Paktors have four different features to allow these machines to run material without plugging: A smooth stainless steel curved inlet feed chute, cage scrapers on the sides and periphery of the cages, an open bottom discharge, and air canon blast ports on the housing. In the case of wet materials, a strong rainstorm can add enough moisture to incoming product to make some equipment nonoperational or incapable of providing consistent product sizing. Cage-Paktors operate well with as much as 15% surface moisture. For particularly difficult material, TerraSource can add several other advanced features, including smooth stainless housing internals, different scraper designs and additional air cannons with specially designed discharge nozzles.
- **High yields, with minimal fines** – Of all impact type equipment on the market, cage mills provide the steepest product curve, typically with 95+% yield of product top size while creating minimal fines. For applications in which product is less than 0.5 in. (12 mm) and down into mesh-size ranges, a cage mill's mix of high yield (material to desired size) and low fines offers a better performance ratio than many other impact type and compression equipment. In addition, cage mills reduce size through pure impact without any attrition or grind action, with more controlled material flow than hammer-type crushers. Cage mills can also run at slower speeds than hammer-type crushers, significantly reducing the amount of fines produced, which can be a critical consideration in situations where processing efficiency and/or adherence to certain environmental guidelines are emphasized. Moreover, because this crusher does not have a screen, no attrition grinding exists, which is a common cause of fines.
- **Longer production of consistent product sizes** – With cage mills, product size stays constant over the life of its wear elements, as opposed to other crushers that produce variable product sizing as components such as hammers and breaker blocks wear down. Even when adjustment mechanisms are provided, the effectiveness of these components relies on ongoing discharge analysis and regular maintenance by knowledgeable service professionals, which can be increasingly difficult to implement due to industry-wide reductions in support staffs.

Design advantages of Cage-Paktors versus traditional cage mills

Even with the overall advantages that cage mills can offer, TerraSource wanted to ensure that our Cage-Paktors provide mining companies with additional performance advantages, as well as more durability (MTBF) and easier, faster and cheaper servicing (MTTR) whenever regular maintenance needs to occur. Cage-Paktors differentiate themselves from other types of cage mills in a number of ways, including

- **Flat face design** – For the majority of applications, Cage-Paktors' flat face design provides significantly more effective and efficient size reduction and fine minimization than any alternative design (such as round pin). Flat face design produces the steepest percentage of passing product curve by ensuring impact and reduction of material with the minimum required quantity and speed of striking elements.
- **Elimination of weld-on liners and introduction of thicker, stronger, more wear resistant components** – The cages of next-generation Cage-Paktors can now be maintained in segments

rather than as a more labor-intensive whole. All pieces of the cage, rather than just the liners, are made of wear resistant material, which makes the structural components much stronger than previous models and adds considerable durability and wear life (Figure 3).

- **Improved striking plate design** – The new striking plate designs of Cage-Paktors offer two distinct advantages: preventing plate ends from cracking or snapping off and minimizing wear on side rings and structural members of the cage, with airflow better controlled through striking plate feature design enhancements. The Cage-Paktor is designed to run striking elements through a stream of rock, often very abrasive, 24/7 at over 100 mph. This relentless flow requires intricate and advanced designs to minimize wear and downtime. The machine's

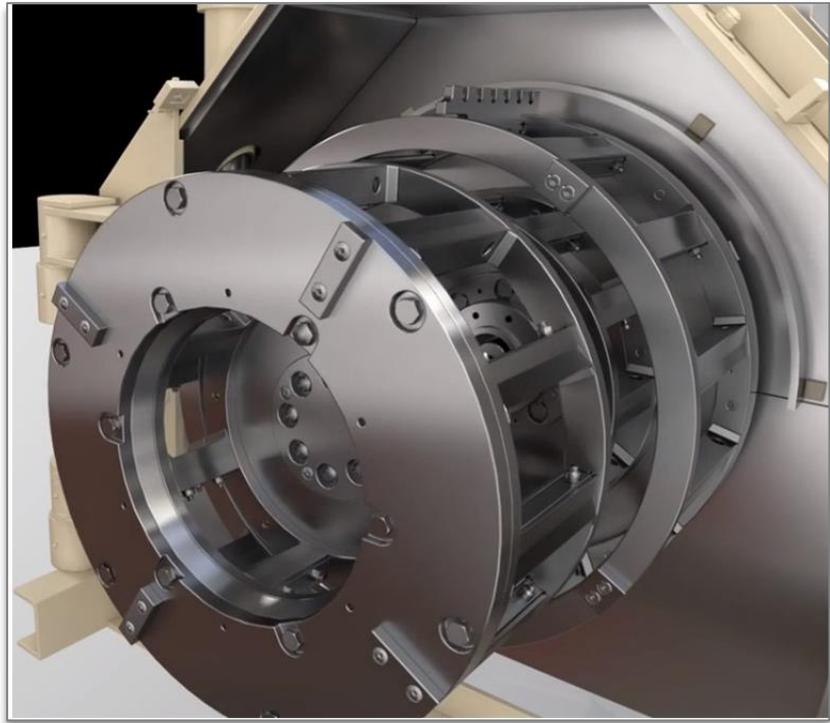


Figure 3 – New segmented cage design with material enhancements

new striking plate design features face baffling and aerodynamic alterations to the profile to redirect flow of fine abrasive particles away from critical structural components, improving crushing efficiency and extending the life of the primary cage structure. TerraSource engineers were also able to thicken rear sections of the striking plate to mitigate tramp-induced breakage, which greatly reduces to the necessity of shutting down the machine for unscheduled repairs.

- **Backward compatibility** – The updated array of cages and striking plates are seamlessly interchangeable with older Cage-Paktor models, offering additional long-term value and reduced capital investment to customers already running these machines. New segmented plug-n-play parts support faster lead times, enable quicker and easier maintenance, lower costs and promote safety.

A variety of benefits to address industry needs

TerraSource engineers continue to advance the Cage-Paktor to provide a viable choice for customers who require low fines while still being able to achieve smaller and smaller product sizing across new types of applications. For many materials, the Cage-Paktor can effectively size material in the 150 - 1000 μm (20 - 100 mesh) range at a high efficiency (percentage passing), a very attractive capability for many operations, especially when considered alongside the machine's minimal footprint, low install cost, and reduced long-term maintenance requirements.

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To discuss the benefits of the Gundlach Cage-Paktor® or any material sizing machinery, contact us at +1-866-231-8153 or email us at info@terrasource.com. Find out more: www.terrasource.com