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Enhancing cement grinding efficiency: Replacing intermediate diaphragms in ball mills

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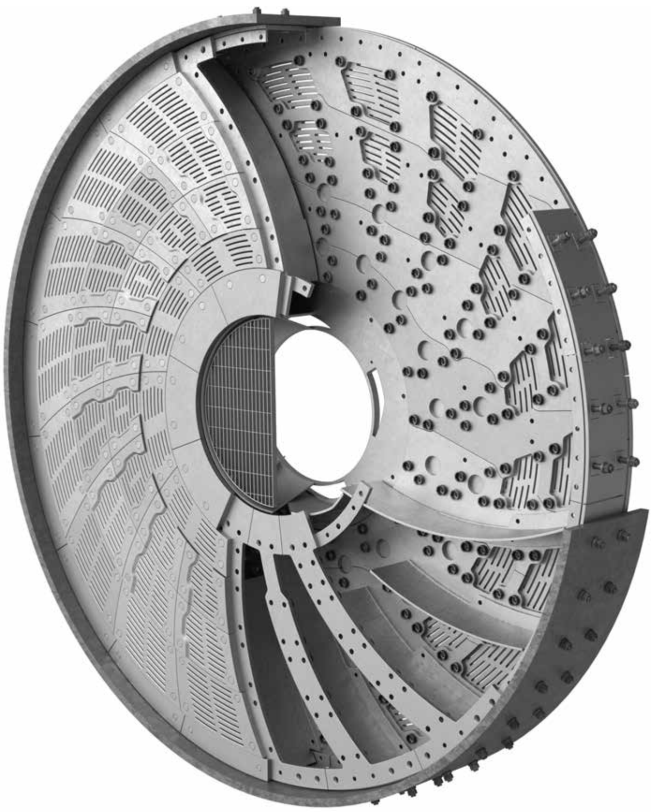
In the global economy, the only product more consumed than concrete is water [1]. As one of the primary inputs for concrete production, cement is also among the most consumed materials worldwide. It is estimated that approximately 4.1 billion tons of cement must be produced annually to meet current societal demands [2], making the energy and environmental impact of its production process highly significant on a global scale.

According to the International Energy Agency [3], the average thermal energy required to produce one ton of clinker – the main raw material for cement – is 3.4 GJ, with most of the energy used (97%) coming from fossil fuels. Meanwhile, the average electrical energy consumption for producing one ton of cement is around 85 kWh (or 0.3 GJ), with most of this energy being consumed in grinding processes. Thus, cement production is a highly energy-intensive process, both in terms of thermal and electrical energy, with total carbon emissions corresponding to about 8% of the global total.



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1 4th generation Christian Pfeiffer intermediate diaphragm

The principles of cement grinding have remained largely unchanged since their inception, based on a balance between crushing and shearing forces to break particles and increase the material's specific surface area. The main modifications to the process over time have come from improvements in available production technologies.

The use of ball mills, a prevalent grinding system worldwide, has undergone significant technological development, sparking divided opinions over time. What began as a simple tube shell consisting of a single chamber filled with grinding media of variable shapes and sizes in wet processes has evolved in the cement sector into far more complex dry process circuits. One of the first significant design modifications from the original process was the division of the tube shell into multiple chambers (typically two) using slotted walls called diaphragms, in order to separate the ball charge into different diameter ranges and to apply specific liners in each chamber to boost a specific grinding effect—crushing or shearing. The crushing effect is enhanced by using larger diameters and liners that pull the grinding media up, increasing the impact force from the media to the material. The shearing effect, on the other hand, requires that the media rolls onto the material instead of impacting it, making liners that can ensure a gradient of diameter sizes throughout the chamber (or classifying effect) more important than lifting the grinding media. Today, multiple chambers have become close to a standard for cement grinding, with the technology paired with other supporting equipment to create a complete grinding circuit, which ranges from basic "open circuits" — where the ball mill receives the raw material and grinds it directly into the finished product at discharge — to "closed circuits" that incorporate an additional separator. The separator allows for more efficient grinding by separating a fraction of the ground material as the finished product while returning the remaining fraction for further grinding in multiple passes.

Although advancements in the original ball mill circuit design have significantly improved system performance, the circuit has a lower maximum throughput and may appear less efficient compared to other available technologies, such as when combined with roller presses or the use

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of single vertical roller mills. Nevertheless, ball mills offer undeniable advantages, such as more accurate product quality control, easier troubleshooting, lower maintenance costs, and, depending on circumstances, even better overall specific energy consumption. While vertical roller mills for cement grinding have been the "trend" of the last decade, ball mill circuits have consistently proven to be a more reliable means of production and are now resurfacing as the preferred grinding technology.

As with any industrial process, ball mill circuits must be routinely assessed and optimized to maintain peak performance. Key actions to preserve circuit efficiency include preventive maintenance, weigher calibration, topping up the ball charge to compensate for grinding media wear losses, internal inspections, material sampling throughout the circuit and inside the mill (known as axial sampling), airflow measurements, constant troubleshooting, and investments in the best available equipment technologies. To achieve optimal results, partnering with experienced suppliers ensures the selection of solutions tailored to specific mill configurations and operational requirements.

While optimization actions and investments in the separator circuit are widespread, the possibilities and advantages of optimizing the grinding process inside the mill itself are often overlooked. However, achieving optimal grinding performance inside the mill is the foundational step to truly optimizing circuit performance. A common issue encountered in ball mills for cement grinding is the wear and inefficiency of intermediate diaphragms. The metal slotted plate walls that divide the grinding chambers inside the mill shell do more than just separate between grinding media diameters to enhance the grinding effect – they play a crucial role in ensuring effective grinding by also maintaining optimal material flow and level on each chamber, stopping nibs from reaching the next chamber and optimizing mill ventilation. Over time, diaphragm components can degrade, leading to poor material flow and ventilation, which bottleneck the system, increase energy demands to achieve the desired product fineness, reduce production rates, and cause operational disruptions along with increased maintenance costs.

To address these challenges, innovative solutions are needed to enhance the performance and durability of intermediate diaphragms while minimizing downtime and operational costs.

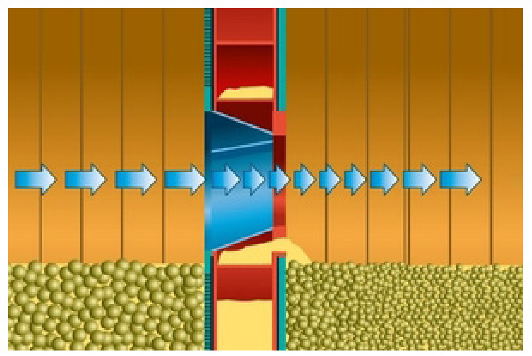
Introducing a High-Performance Solution

Replacing traditional intermediate diaphragms with advanced designs such as Christian Pfeiffer's design seen in Figure 1 offers a promising solution to some of the challenges faced in cement grinding. High-performance diaphragms, engineered with modern materials and innovative configurations, address inefficiencies and deliver long-term benefits that far outweigh initial investment costs. Adopting advanced diaphragm designs not only improves operational efficiency but also supports broader industry objectives, such as cost reduction and environmental stewardship.

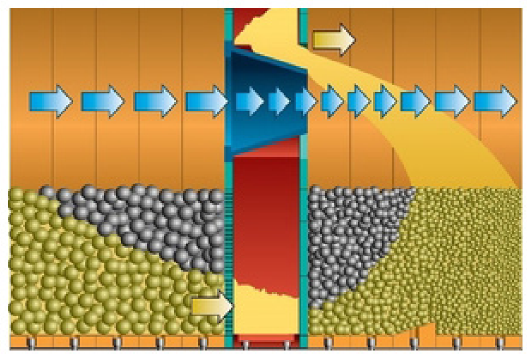
Key features of these advanced diaphragms include:

- Superior Ventilation: Optimized airflow channels ensure better heat dissipation and prevent clogging, contributing to consistent mill performance.
- Optimized Material Flow: Improved discharge designs ensure complete separation between air and material flows, preventing the material from being propelled by airflow. This allows better use of available grinding volume and avoids overloading or underloading in specific sections of the mill.
- Improved Durability: High-strength alloys and wear-resistant coatings extend diaphragm lifespan, reducing maintenance frequency and eliminating fatal failures such as plate breakages.
- Ease of Installation: Modern designs facilitate quicker replacements, minimizing downtime during installation.

The successful implementation of diaphragm replacements requires careful planning and execution. Each mill operates under unique conditions, such as raw material properties and grinding requirements. Customizing diaphragm designs to match these parameters ensures optimal performance. Providing proper training for plant operators and maintenance teams enhances their ability to manage the new diaphragms effectively,



2 (a) **Material and airflow inside the mill with old diaphragm designs**



2 (b) **Material and airflow inside the mill with Christian Pfeiffer 4th generation diaphragm design**

reducing operational risks. Additionally, proactive monitoring, adjustments, and maintenance further extend diaphragm lifespan. Achieving these factors at their best relies on collaboration with a reliable supplier with long-term expertise in cement grinding equipment.

Case Study: Efficiency Gains Through Diaphragm Replacement

To demonstrate the impact of replacing intermediate diaphragms, consider a case study of a cement plant's ball mill with 4.6 m diameter and approximately 14.0 m effective grinding length, optimized by an intermediate diaphragm upgrade in partnership with Christian Pfeiffer.

After conducting a comprehensive mill inspection and circuit assessment, the key issues were identified by Christian Pfeiffer as:

- Old intermediate diaphragm design, with only a basic material transport design and no flow control.
- High blockage of the intermediate diaphragm slots with scrap material.
- Large gaps between intermediate diaphragm plates, caused by the impact of the grinding media.
- High wear on the backside of the intermediate diaphragm.
- Poor condition of liners in both chambers, including low activating effect, broken liners, and no classifying effect.
- High material coating at all mill internals of both chambers.

The plant decided to replace the existing intermediate diaphragm with an advanced high-performance Christian Pfeiffer intermediate diaphragm optimized for the mill's operating conditions, with minimal disruption to production for installation purposes. As part of the installation procedure, the mill ball charge was sorted to remove nibs and scrap material, and the mill was later refilled with an optimized ball charge distribution. Although found in poor condition, the mill liners were not replaced at this step. As part of the commissioning of the new component, a Christian Pfeiffer engineer assessed the system to ensure the maximum optimization.

The significant improvements achieved in the mill performance by the diaphragm upgrade and following process optimization by the Christan Pfeiffer expert can be seen in Table 1, which compares the circuit's performance for the same product composition of 65% clinker and 30% secondary cementitious materials (limestone and pozzolan), and same fineness of average 3% residue on 45 µm, before and after the diaphragm replacement.

The optimized material flow, ventilation and grinding length provided by the intermediate diaphragm, together with the new sorted and optimized ball charge, enabled a 14% increase in output, allowing the plant to meet growing market demands without additional infrastructure investments. The significant reduction in the energy consumption per ton of cement translates into substantial cost savings, enhancing the plant's overall profitability. The achieved improvements also align with the plant's sustainability goals, since the increase in efficiency contributes to reducing the final product carbon footprint not only due to the reduced specific power consumption, but also due to the promising potential for future reducing of the clinker factor in the cement composition, setting the path towards a greener cement production.

Table 1 **Comparison of mill circuit performance before and after the intermediate diaphragm upgrade (for same product composition and fineness)**

	Before	After	Improvement
Material throughput (dry)	112 t/h	127.7 t/h	14%
Mill motor specific power consumption	36.55 kWh/t	32.05 kWh/t	-12.3%

The actual improvement potential of a diaphragm upgrade may vary according to the original state of the operation and the mill internals, and must be aligned with the sorting of the ball charge and optimization of the process conditions by an expert. Christian Pfeiffer's experience shows that at least a 5% improvement can be expected by replacing an older diaphragm design. The correspondent monetary savings and Return on Investment figures can be calculated using Christian Pfeiffer's Diaphragm ROI Calculator, available at the website [4].

Conclusion

The presented case study underscores the transformative potential of diaphragm replacement, offering a practical blueprint for cement plants aiming to enhance their grinding operations. As the industry continues to prioritize sustainability and cost efficiency, such innovations will play an increasingly vital role in shaping its future.

Additionally, this approach highlights the importance of continuous innovation and adaptation in the cement industry. By embracing advanced technologies and materials, plants can not only improve their competitiveness but also contribute meaningfully to global sustainability efforts. The path forward is clear: investing in high-performance solutions today will yield significant dividends for the cement plants of tomorrow.

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