Upgrading existing separators to lower the clinker factor

This article highlights key strategies for reducing the clinker factor within existing ball mill-based grinding plants, helping producers transition to more sustainable and cost-effective cement production. Upgrade options for existing separators are reviewed, including technical requirements and potential bottlenecks.

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Reducing the clinker factor of cement has become one of the most effective strategies for cement producers seeking to lower their environmental footprint while maintaining competitive production costs. Because clinker is the most energy- and CO_2-intensive component of cement, every percentage point of reduction directly decreases the overall fuel consumption in the kiln (in relation to the total amount of produced cement) and reduces process emissions. In an industry under increasing regulatory pressure and facing rising energy prices, optimising the clinker factor is no longer optional, it is a strategic necessity.

At the same time, many cement plants are operating with long-established grinding circuits built around ball mills. While robust and reliable, these systems were originally designed for cements with higher clinker content and limited additive usage. Increasing the share of supplementary cementitious materials (SCMs) such as limestone, slag, or fly ash introduces new challenges in terms of product fineness, reactivity and overall cement performance. Achieving competitive strengths with lower clinker content requires a higher degree of grinding efficiency and separation accuracy than many existing installations can deliver.

For operators seeking to reduce the clinker factor without replacing their entire grinding infrastructure, a targeted modernisation approach offers a practical solution. Improvements in additive utilisation, finer clinker grinding and upgraded separator efficiency can significantly enhance performance. These measures allow existing ball mill systems to achieve higher throughput, improved product quality and better energy efficiency, while simultaneously supporting corporate CO_2 reduction goals.

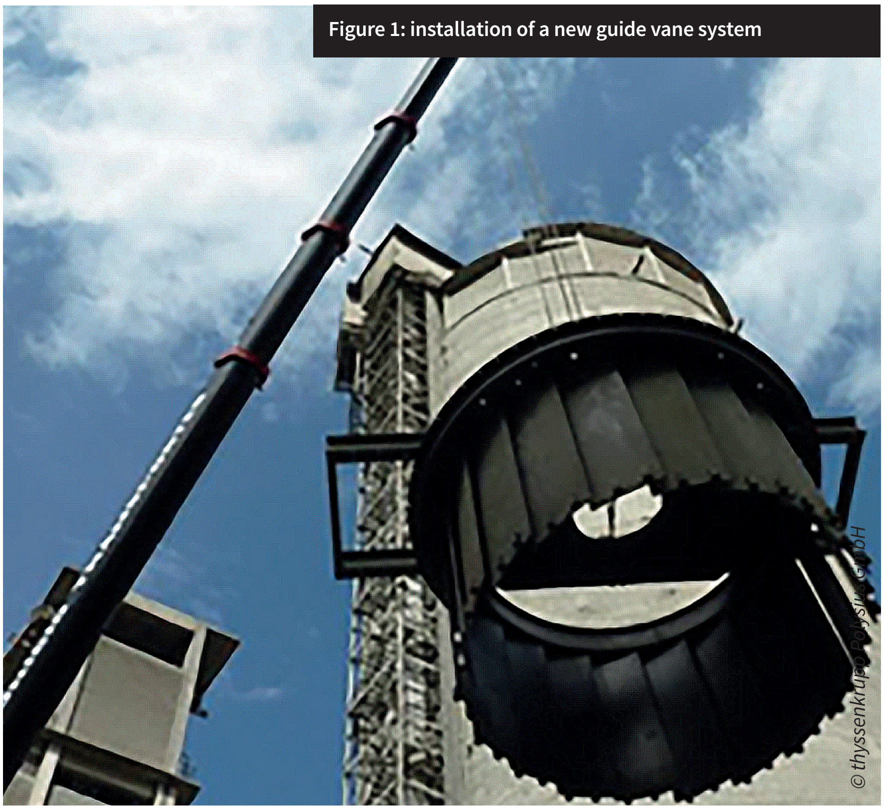


Figure 1: installation of a new guide vane system

The role of additives in clinker reduction

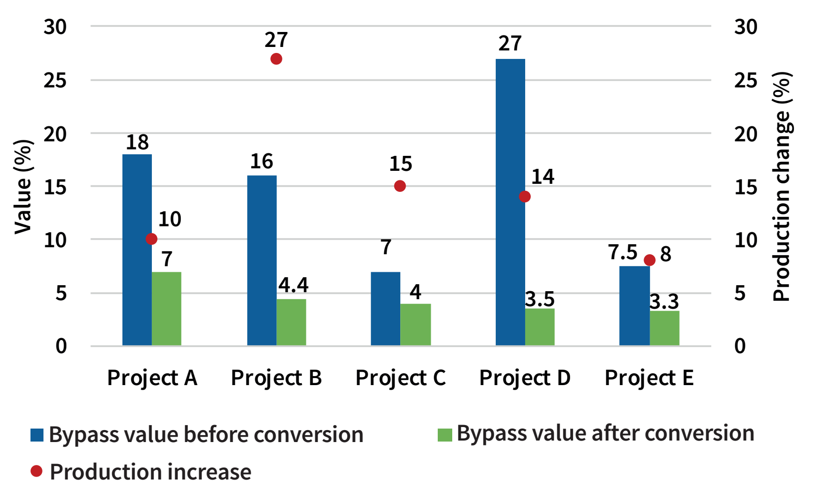
The use of mineral additives has become a central strategy for lowering the clinker factor in modern cement production. Materials such as limestone, granulated blastfurnace slag, fly ash, natural pozzolans, or calcined clays can replace a significant share of clinker while maintaining or even enhancing cement performance. Each percentage of SCMs directly reduces CO_2 emissions tied to energy-intensive clinker production and offers a clear economic advantage through reduced fuel consumption and greater use of locally available materials.

However, achieving high additive replacement levels depends heavily on the reactivity of the remaining clinker fraction as well as on the reactivity of the SCM. Because the added SCMs do not contribute much to the hydration process, the contribution of the remaining clinker to the early and final strength becomes more critical.

In summary, effective clinker reduction is not only about adding more SCMs, it requires ensuring that the remaining clinker is sufficiently reactive.

Because of the lower reactivity of the SCMs, this clinker must release its

Figure 2: process and production results of the installation of a new guide vane system – bypass comparison over normalised circulation (U=2)



Source: thyssenkrupp Polysius GmbH

hydration products rapidly and effectively when mixed with the SCMs. This is only possible when the clinker is ground to a higher fineness, which leads to a greater exposed surface area available for chemical reaction, which accelerates the formation of hydration products and improves early strength development.

This early strength development is the result of the rapid formation of calcium silicate hydrate gel, which is the hydration reaction result of alite and belite, the main components of clinker. The fact that finer clinker particles hydrate more quickly is of utmost importance, because large volumes of SCMs are used and the remaining fraction of clinker must work harder in the initial hours and days to achieve target strengths.

Although additives such as slag or pozzolans offer significant long-term strength potential, their activation relies on sufficient calcium hydroxide and heat from clinker hydration. A more reactive, finely ground clinker supports these secondary reactions, enabling higher additive replacement without compromising performance.

Tighter particle size distribution (PSD), which is only possible with efficient separation, leads to more predictable hydration behaviour. Large coarse particles that remain unground contribute little to early strength and can negatively affect mortar or concrete homogeneity.

However, many existing ball mill systems were designed for traditional ordinary Portland cements with relatively high clinker content and moderate fineness targets. Increasing clinker fineness places greater demands on the mill and separator, often pushing equipment towards its performance limits. Separator efficiency becomes particularly decisive because the finer the required clinker fraction, the more precisely coarse and fine particles must be separated. This constant and precise separation leads to an even and tight PSD, which ultimately leads to predictable and consistent strength development.

Technical limitations of existing separators

One of the limitations of the separators is a low separation efficiency, where older separators allow significant quantities of coarse particles to pass into the final product as well as a large proportion of fine material to be returned to the mill. Both effects lead to inefficient separation.

Oversized particles in the final product contribute little to strength, and product-sized particles returned to the mill reduce the throughput of the mill and ultimately increase its specific energy consumption. Another limitation is the limited adjustability of older separators. Many first- and second-generation separators offer restricted flexibility to adapt to the new fineness targets required for high-SCM cements.

These bottlenecks prevent operators from achieving the finer clinker grinding needed to support higher SCM levels. Therefore, separator modernisation becomes a pivotal step for any plant planning to reduce the clinker factor without sacrificing product quality or mill capacity.

Upgrading separator efficiency

As cement producers aim to increase clinker fineness and incorporate higher volumes of SCM, the performance of the separator becomes a decisive factor in the efficiency and quality of the grinding process. In many existing ball mill plants, first- or second-generation separators represent the primary bottleneck preventing finer, more consistent product quality. However, modern separator technologies offer substantial improvements in precision, flexibility and energy efficiency, making them one of the most impactful upgrade options for clinker reduction strategies.

The separator governs two critical aspects of the grinding circuit. First, the classification accuracy to ensure that only particles meeting the target fineness reach the final product. When the separator underperforms, coarse particles slip into the finished cement, undermining strength development, especially in low clinker blends where each gram of clinker must hydrate efficiently.

Secondly, internal circuit balance: returning oversize particles to the mill while avoiding unnecessary overgrinding of fines. Excessive fines returning to the mill increase the circulating load, reduce throughput and raise specific energy consumption.

Separator upgrade modules: a practical path to higher efficiency

Many existing separators can be significantly enhanced through modular upgrades that address fundamental aerodynamics and separation precision. Typical modernisation packages include an enhanced guide vane system or an optimised airflow through the separator:

- **Enhanced guide vane systems**
  New curved guide vane systems (see Figure 1) improve airflow distribution and reduce bypass. Better airflow stabilises the separation zone, lowering the proportion of coarse particles in the final cement and enabling tighter control of particle size distribution. Figure 2 shows the result of the implementation of an enhanced guide vane system.
- **Optimised airflow by reduction of pressure drop**
  Another possible upgrade of existing separators is the installation of further guide plates to reduce the pressure loss across the separator. This was analysed and developed through numerous simulations (see the rotor in Figure 3).

Figure 3: model of optimised rotor for simulation purposes

This upgrade leads to an increase in production by increasing the air volume, or to a decrease in power consumption at the same air volume. Both ultimately result in an improvement of specific power consumption.

In the most recent cases, throughput optimisations of up to five per cent were achievable, following an upgrade that is installed within a short downtime of three days (see Figure 4).

Performance benchmarks

Across a range of retrofit projects, plants upgrading from older separators to modern high-efficiency systems typically achieve:

- an average of 8-12 per cent and up to 27 per cent increase in mill throughput
- 5-8 per cent reduction in specific energy consumption
- significant improvement in reduction of bypass and ultimately reduction of circulation load.

Such results underline the value of targeting the separator as a key modernisation component when preparing existing grinding circuits for higher additive usage and more demanding fineness specifications.

Conclusion

Reducing the clinker factor has become a strategic pillar for cement producers striving to lower CO_2 emissions, optimise energy use and enhance long-term competitiveness. Achieving this goal within existing grinding infrastructures, especially those centred around ball mills, requires a co-ordinated set of modernisation measures that collectively unlock higher clinker reactivity, increased grinding capacity and improved overall efficiency.

A key enabler is finer clinker grinding, which ensures that the remaining clinker fraction provides sufficient hydration activity to support high levels of SCMs. However, finer grinding alone is not feasible without addressing the limitations of many older separators. Upgrading to modern, high-efficiency classification systems significantly sharpens the separation cut, reduces bypass and stabilises mill performance, allowing plants to achieve the fineness required for low-clinker cements without sacrificing throughput. ■

Figure 4: industrial implementation of guide plates