THE AI ADVANTAGE

Molly Pace, Imubit, explains how closed loop AI optimisation is reshaping cement manufacturing by boosting efficiency, reducing emissions, and enabling real-time process control.

Cement manufacturing, a cornerstone of global infrastructure, is undergoing a significant transformation driven by the need to improve energy efficiency and reduce emissions. This change comes as the industry faces mounting pressure to address its environmental footprint; it is currently responsible for approximately 8% of global CO_2 emissions. A key enabler in this transformation is a new closed loop AI optimisation (AIO)

approach, which offers a fresh perspective on process control and online optimisation.

The most significant operational challenges facing cement plants today are multi-faceted, encompassing raw material availability and variability. Unpredictable volumes, inconsistent frequency, and fluctuating quality of supply lead to irregular clinker quality, reduced plant productivity, and elevated emissions. Furthermore, ageing equipment compounds these issues throughout production campaigns, as wear and tear on critical components of the cement manufacturing process progressively diminishes production capacity and process efficiency.

Variability in raw material quality is particularly problematic in cement production, as it can lead to mechanical, environmental, operational, and safety challenges. Fluctuations in raw material quality directly affect the chemical

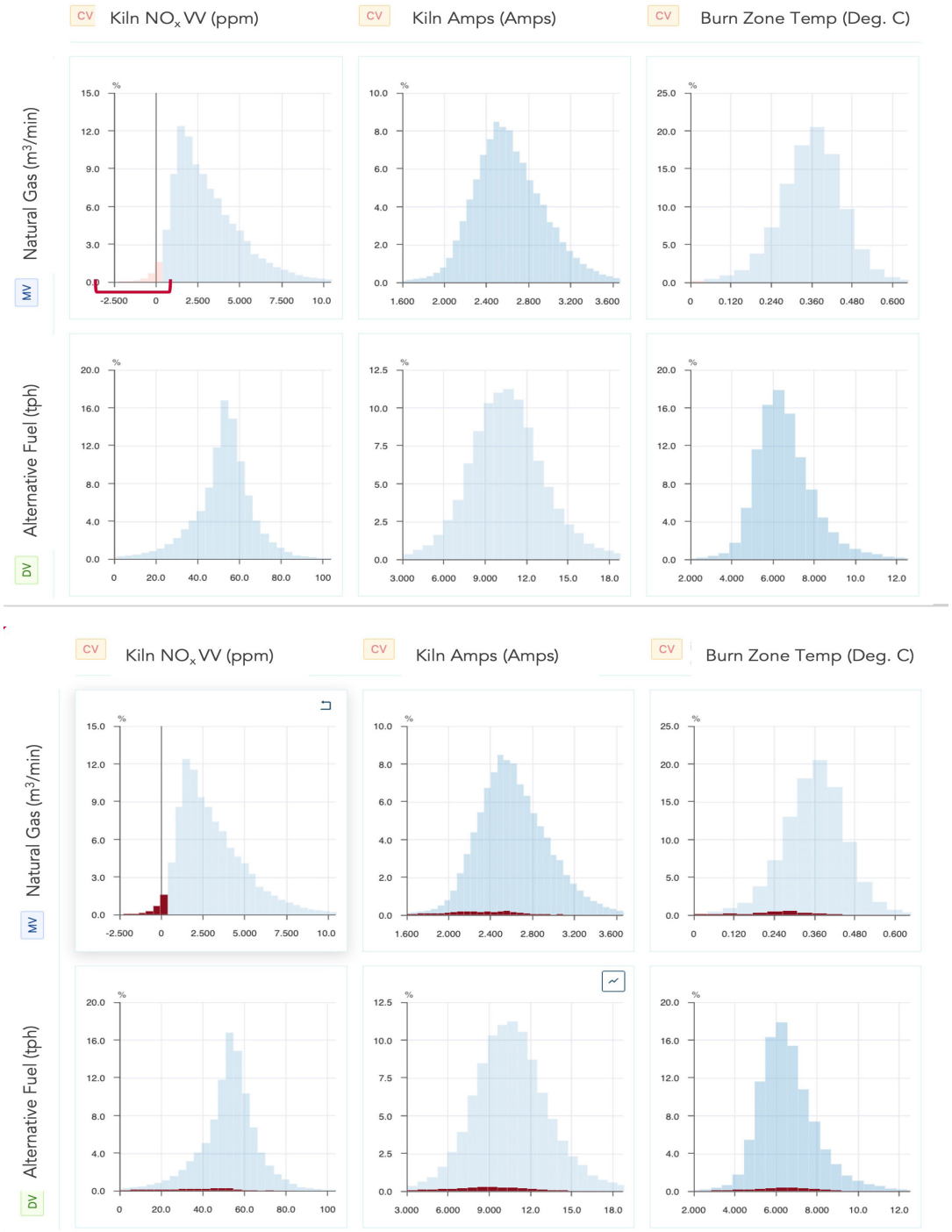

Figure 1. Unfiltered relationship matrix (top, grey) shows all possible values of each relationship learned by the AI model during training. Filtered relationship matrix (bottom, red) highlights the nonlinear relationship between natural gas flow and kiln NOx calling out behaviour of other variable pairs when this relationship is negative.

reactions involved in clinker formation, which, in turn, influence the overall quality of clinker production.

Similarly, variability in the type and quality of fuel can disrupt the temperature profile and heat distribution in the kiln, causing over-burning or under-burning of clinker and adversely impacting its quality and reactivity. Additionally, changes in ambient conditions and humidity can influence the hydration reaction of the cement product and the efficiency of heat transfer during the process.

The path to a low carbon future

Decarbonising cement production centres on minimising CO_2 emissions generated during the calcination process.

A key lever in this effort is reducing the clinker factor – the percentage of clinker used in cement production. However, the two primary challenges here are maintaining throughput demand and adhering to product quality standards, both of which directly affect profitability.

Clinker factor reduction is achieved by substituting clinker with other raw materials or industrial by-products, collectively known as supplementary cementitious materials (SCMs). Examples of SCMs include fly ash, calcined clay, calcined shale, and slag cement.

While increasing the proportion of SCMs lowers the clinker factor, it often compromises cement performance, particularly mortar strength.

This issue can be mitigated by enhancing cement fineness or increasing clinker reactivity, both of which significantly impact the cement grinding process.

Higher cement fineness demands greater energy consumption to grind clinker into fine powder.

Conversely, using more reactive clinker facilitates easier grindability at higher fineness targets due to its mineralogical composition, particularly its high alite (C3S) content. This is crucial for counteracting the mortar strength reduction associated with higher SCM usage.

Alternative fuels (AF) also play a pivotal role in decarbonising the industry, as approximately 40% of cement industry CO_2 emissions stem from fossil fuel use. Introducing and sustaining AFs in the production process, known as co-processing, is vital for strengthening the circular economy.

While other decarbonisation methods aim to reduce specific gross emissions (the total amount of CO_2 emitted per tonne of cement), the adoption of AFs contributes to lowering the absolute gross emissions (the total CO_2 output) of a cement plant.

Moving beyond traditional process control

Traditional methods, such as model predictive control (MPC), have long played a vital role in stabilising plant operations. However, these systems rely on fixed models and often require manual intervention, making them less effective in addressing the complexities of modern cement production. Enter closed loop AIO, a system designed to adapt in real-time to the dynamic conditions of a cement plant. By leveraging advanced machine learning techniques, AIO redefines operational efficiency and sustainability.

Closed loop AIO presents significant opportunities for data-driven decision-making, surpassing the limitations of MPC, which relies on predefined relationships. This advanced optimisation approach evolves alongside the site, pushing the plant to achieve a continually higher state of optimisation.

Closed loop AIO systems can support the cement industry's decarbonisation goals in two key ways. Firstly, they provide deeper insights into the relationships between process variables (Figure 1) and the carbon emission costs of various operational modes. For instance, operating at half production capacity does not necessarily halve emissions. Secondly, they enable carbon emission costs to be integrated into the economic objective function that guides optimisation strategies.

Cement manufacturing processes are inherently complex, involving multiple variables such as fuel composition, kiln feed, and ambient conditions. While MPC has improved stability, its limitations become evident in highly variable environments.

Closed loop AIO addresses these challenges using reinforcement learning to learn from a plant's history. Unlike traditional systems operating within predefined boundaries, AIO simulates both historical and never before seen process conditions, enabling plants to maintain optimal performance under fluctuating conditions.

This adaptability is critical for an industry striving to meet ambitious decarbonisation targets.

Imubit's 'Optimising Brain', an AIO solution, provides real-time insights that enhance both productivity and sustainability. By integrating with existing infrastructure, the system optimises critical components such as kilns, coolers, and preheaters.

The AIO creates a digital twin of the plant, learning from historical data to make decisions that improve efficiency while reducing emissions – a level of insight that was previously unattainable.

One significant advantage of AIO is its ability to minimise reliance on manual intervention, which has become increasingly important as the industry faces a skills gap. With experienced operators retiring, AIO helps standardise optimisation techniques, ensuring consistent performance across shifts and locations.

A practical approach to innovation

The adoption of AIO by a top global cement company exemplifies how the technology can be effectively implemented. Imubit selected one of its most optimised plants as a pilot site to test AIO's capabilities.

The pilot highlighted several key outcomes, including reduced fuel consumption, lower CO_2 emissions, and enhanced production flexibility. By creating a plant simulator for operator training, Imubit also hopes to address workforce turnover, ensuring newer operators can quickly onboard and adapt to the demands of modern cement production.

The broader implications of AIO extend beyond operational efficiency. The technology aligns with the industry's sustainability goals by optimising the use of AFs and improving energy management.

Collaboration between operators and AI systems has been a cornerstone of Imubit's success. By combining human expertise with machine intelligence, Imubit has improved plant performance and enhanced operator satisfaction. This partnership underscores the potential of AIO to serve as a transformative tool for the cement industry.

A measured path to industry-wide adoption

As the cement sector navigates the dual challenges of decarbonisation and operational complexity, closed loop AIO emerges as a practical solution. Its ability to adapt to changing conditions and deliver real-time insights positions it as a key driver of efficiency and sustainability. Imubit's experience demonstrates that AIO is not merely a replacement for traditional systems but a complementary enhancement that unlocks new performance levels.

The journey toward widespread adoption of AIO in cement manufacturing is just beginning. AIO represents a significant step forward for an industry at the crossroads of tradition and innovation by addressing immediate operational needs while supporting long-term sustainability goals.

Through careful implementation and a commitment to collaboration, the cement sector can harness technology to build a more efficient and environmentally responsible future. ■