CEMENT WHITE PAPER

Optimising Kiln-line Performance in Cement Production

Executive Summary

In a global cement market increasingly driven by cost efficiency, sustainability, and regulatory compliance, optimising kiln systems has become more than a production exercise - it is a strategic necessity. This whitepaper outlines a comprehensive, technically grounded approach to improving kiln performance through reduced exhaust gas volumes, improved combustion efficiency, effective fuel substitution, and advanced modeling techniques such as CFD. The ultimate goal is to enable cement producers to enhance fuel flexibility, reduce emissions, and increase profitability without sacrificing clinker quality or system reliability.

1. Introduction

Traditionally, kiln performance has been equated with daily clinker output. However, today’s competitive and environmentally conscious industry landscape calls for deeper performance metrics - particularly those related to energy consumption and emissions. Modern optimization seeks to balance high throughput with low energy input and effective use of alternative fuels, all while navigating the complex thermal and material interactions of the pyroprocess.

2. Understanding Exhaust Gas Dynamics

2.1 Specific Exhaust Gas Volume: A Core Metric

Specific exhaust gas volume (EGV), measured as Nm^3 per ton of clinker, is a critical metric. It directly affects:

- The size and power requirements of downstream fans and filters
- Fuel efficiency and CO_2 emissions
- Equipment wear and maintenance intervals

High EGV is typically a symptom of inefficiencies in combustion, air ingress, fuel moisture, or heat recovery. Reducing EGV can unlock additional kiln capacity and increase the share of lower-cost secondary fuels.

2.2 Beyond Fan Upgrades

Though upgrading ID fans can temporarily alleviate throughput bottlenecks, it's a symptomatic fix. Process-based solutions—such as improving heat exchange efficiency and sealing air ingress—tackle root causes and offer compounding benefits.

3. Process Parameters Influencing Kiln Efficiency

3.1 Fuel Properties

Substitution of fossil fuels with secondary fuels introduces variability:

- Moisture Content: Raises latent heat demand and EGV.
- C/H Ratio: Fuels with high carbon content need more oxygen, thus increasing nitrogen from air and total gas volume.
- Combustion Characteristics: Lumpy or low-reactivity fuels may require extended residence times or hotter zones.

3.2 Clinker and Raw Mix Composition

- High alite content increases burning zone temperature.
- Tight free lime specifications can escalate energy needs.
- Adjustments in raw mix or grinding fineness may provide energy-saving opportunities.

3.3 Heat Recuperation Efficiency

The clinker cooler, often overlooked, plays a vital role. Each kilojoule not recovered from hot clinker must be replaced with additional fuel. Optimization may involve:

- Grate speed adjustments
- Cooler air management
- Design retrofits for improved heat exchange

4. Primary Air and Flame Optimisation

4.1 Minimising Primary Air Demand

While primary air is needed for flame stabilization and momentum, excessive use introduces cold air that degrades thermal efficiency. Strategies include:

- High-momentum, low-primary-air burners
- Swirl and axial air management
- Optimising secondary air paths from the cooler

4.2 Flame Shape and Heat Profile

An ideal flame shape promotes uniform heat transfer and avoids local hot spots or cold zones. Influencing factors include:

- Burner (nozzle) design
- Swirl numbers and primary air flow rate
- Fuel particle size and distribution
- Air-fuel mixing dynamics

A tailored flame profile reduces dust entrainment, improves coating stability, and minimizes wall stress - all contributing to lower EGV.

5. Calciner Optimization

5.1 Role of the Calciner

Modern calciners consume the majority of fuel input. Efficient fuel and meal mixing is crucial:

- Poor fuel distribution → Incomplete combustion
- Poor meal dispersion → Inconsistent calcination
- Design issues → Short-circuiting, particle spillage into kiln inlet

5.2 Strategies for Improvement

- Improve suspension uniformity through tailored inlet geometries
- Reduce deflections and dead zones that cause particle dropout
- Use CFD to simulate particle trajectories and optimize retention times
- Tune operating parameters for staged combustion to balance NO_x reduction and burnout

6. Preheater Efficiency

The cyclone preheater is critical for upstream energy recovery. Optimization focuses on:

- Suspension Efficiency: Enhanced by splash box designs
- Separation Efficiency: Dictated by cyclone geometry and dip tube configuration

Any gain in cyclone efficiency translates directly into lower fuel demand and lower EGV.

7. Controlling False Air Ingress

False air is ambient air that unintentionally enters the system, diluting gas streams and increasing fan load without contributing to combustion or material transformation. Common sources:

- Leaking flanges and seals
- Worn or poorly maintained kiln seals
- Gaps in ducting and expansion joints

An audit can often identify and prioritise sealing efforts that pay back rapidly in fuel savings and reduced fan stress.

8. The Role of CFD Modeling in Optimization

Computational Fluid Dynamics (CFD) has emerged as an essential tool in kiln optimisation. It enables:

- Visualisation of gas and particle flows in complex geometries
- Identification of inefficiencies in combustion, mixing, and residence time
- Virtual testing of design modifications before costly physical implementation

CFD provides quantitative insights that can drive decisions confidently and precisely, especially in calciners and preheaters where flow patterns are three-dimensional and counterintuitive.

9. Strategic Recommendations

- Benchmark exhaust gas volume and compare against best-in-class standards.
- Prioritise fuel substitution strategies that minimise moisture and maximise reactivity.
- Undertake periodic CFD studies to refine the design and operation of calciners and burners.
- Monitor and control false air systematically through inspections and real-time measurements.
- Adopt a holistic optimisation philosophy integrating design, operations, and controls.

10. Conclusion

Kiln line optimisation is no longer about brute-force capacity increases. It is about operating smarter - with lower energy, higher fuel flexibility, and tighter environmental control. By addressing specific exhaust gas volume and enhancing thermal and material efficiencies throughout the pyro line, cement producers can reduce costs, cut emissions, and improve the robustness of their operations. When supported by advanced diagnostics and modeling tools, even small changes can yield substantial and sustainable returns.