White Paper

Detecting and compensating missing inkjet nozzles in ceramic tile printing

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Executive summary

In ceramic tile manufacturing, industrial inkjet printing has become the dominant method for high-quality decoration. However, nozzle failure remains a persistent and costly challenge, directly impacting production efficiency, material usage, and final product quality.

Operating with high-density, pigment-rich inks in demanding factory environments, ceramic inkjet systems are particularly susceptible to instability at the nozzle level. While certain visual defects may initially be masked by natural tile textures, underlying issues can escalate quickly, leading to contamination, progressive nozzle loss, and unplanned downtime.

This white paper examines the causes and consequences of nozzle failure in ceramic tile printing, highlighting the limitations of conventional detection methods. It then introduces Meteor Inkjet's Nozzle Health Technology™ (NHT), an electrical sensing approach that enables real-time monitoring of nozzle performance without interrupting production or consuming media. When combined with NozzleFix™ compensation algorithms, this approach provides a practical pathway to maintaining consistent print quality while reducing waste and downtime.

Introduction

The adoption of digital inkjet technology has transformed ceramic tile decoration, enabling greater design flexibility, faster product changeovers, and efficient mass customisation. These advantages, however, depend on the consistent performance of increasingly complex print systems.

Modern ceramic printers typically operate in single-pass configurations, using multiple print bars to apply colour at high speed. In this context, each nozzle contributes directly to the final image. A failure in even a single nozzle can result in visible streaking across large volumes of tiles, making nozzle reliability a critical factor in both quality and productivity.

This challenge is further compounded by the realities of ceramic manufacturing environments, where harsh conditions and continuous operation place sustained demands on inkjet systems. Understanding how these factors interact is key to addressing the problem of nozzle failure.

The ceramic printing environment

Ceramic tile printing presents a uniquely demanding environment for inkjet systems. The inks used are heavily loaded with inorganic pigments and particles, which increases their tendency toward sedimentation and makes them inherently more challenging to handle than inks used in other sectors. In parallel, production environments often contain airborne dust and particulate matter, raising the risk of contamination at the nozzle plate.

Another important factor is waveform optimisation. In ceramic applications, incorrectly tuned drive waveforms can generate satellite droplets that accumulate on the printhead faceplate. This leads to wetting effects that interfere with droplet formation and can initiate further instability in jetting behaviour.

Although the natural variation in tile designs can sometimes mask minor defects, this apparent tolerance can conceal underlying issues. If left unaddressed, these issues may develop into more visible defects, increased maintenance requirements, and interruptions to production. Taken together, these environmental and process conditions create a setting in which nozzle reliability is continually under pressure.

Why nozzle failures are so prevalent in ceramics

Within this challenging environment, the high incidence of nozzle failure is further amplified by the scale and nature of ceramic production. Modern inkjet systems incorporate large arrays of nozzles operating continuously at high speed, meaning that even low individual failure rates translate into frequent defects at the system level.

At the same time, the continuous, single-pass nature of tile production limits opportunities for inspection and intervention. Problems are rarely identified at the point of origin and instead persist until they become visible in printed output, by which stage they may already have affected significant volumes of product. As a result, the conditions described above do not simply increase the likelihood of individual failures - they make failure a systemic and ongoing risk.

Causes of nozzle failure in ceramic printing

Understanding this systemic risk requires a closer look at the underlying failure mechanisms. In ceramic applications, nozzle failures arise from a combination of fluidic, environmental, and mechanical effects. Air ingestion can disrupt the continuity of ink flow, while dissolved gases may come out of solution and form bubbles within the nozzle. The high solid content of ceramic inks increases the likelihood of internal

clogging, particularly where sedimentation or particle agglomeration occurs.

External contamination also plays a significant role. Dust and debris can accumulate on the nozzle plate, leading to partial or complete blockage. In addition, wetting effects caused by misting or satellite droplets can spread contamination across the faceplate, exacerbating nozzle disruption and contributing to progressive failure.

Mechanical and electrical faults may also occur, including degradation of the piezoelectric actuator or failures in the drive circuitry, although these tend to be less frequent than fluidic and contamination-related issues. Together, these mechanisms explain how the environmental and operational pressures in ceramic printing translate into real and recurring nozzle failures.

The challenge of detecting nozzle issues

Given the conditions described, identifying nozzle failures in ceramic tile production is far from straightforward. Traditional camera-based inspection systems face significant limitations, as the textured and patterned nature of tile surfaces can obscure defects. Detecting a missing nozzle within a complex design often requires high-resolution imaging and advanced processing, making such systems costly and difficult to implement reliably in a production environment.

Test patterns can simplify detection, but they interrupt production and consume valuable materials, which is impractical in high-volume manufacturing. As a result, many defects are only discovered after they have already impacted output.

Electrical sensing methods offer an alternative approach, but historically they have been limited by integration challenges and the difficulty of extracting meaningful information in real time. This creates a clear need for a detection method that operates continuously, non-invasively, and without reliance on printed output.

A new approach: Nozzle Health Technology™

Addressing this need, Meteor Inkjet's Nozzle Health Technology™ introduces a fundamentally different approach to monitoring nozzle performance. By integrating electrical sensing into the printhead drive electronics, the system measures the impulse response of each nozzle in real time.

This is achieved by analysing the residual oscillation of the piezoelectric actuator following excitation. The resulting signal provides a direct indication of nozzle condition, enabling the system to distinguish between normal jetting behaviour and failure modes such as blockage, air ingestion, or wetting.

Because this method does not rely on printed output, it eliminates the need for test patterns and avoids the associated waste of tiles and ink. It is also independent of ink colour or opacity, making it particularly well suited to ceramic applications where visual detection can be unreliable.

In practice, this allows manufacturers to assess printhead health before production begins, verify the effectiveness of cleaning or purging operations, and monitor nozzle performance continuously without interrupting the process. In doing so, it shifts nozzle management from a reactive to a proactive process.

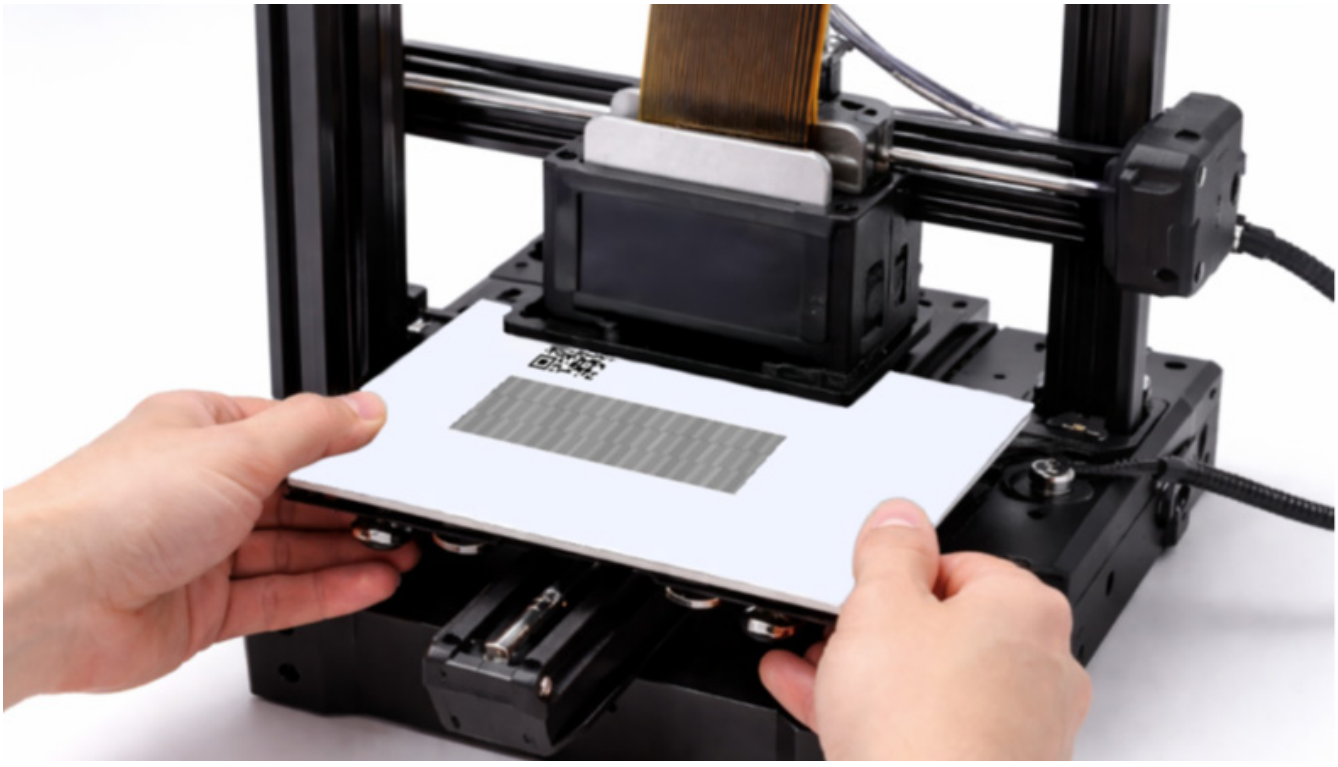
Real-time compensation with NozzleFix™

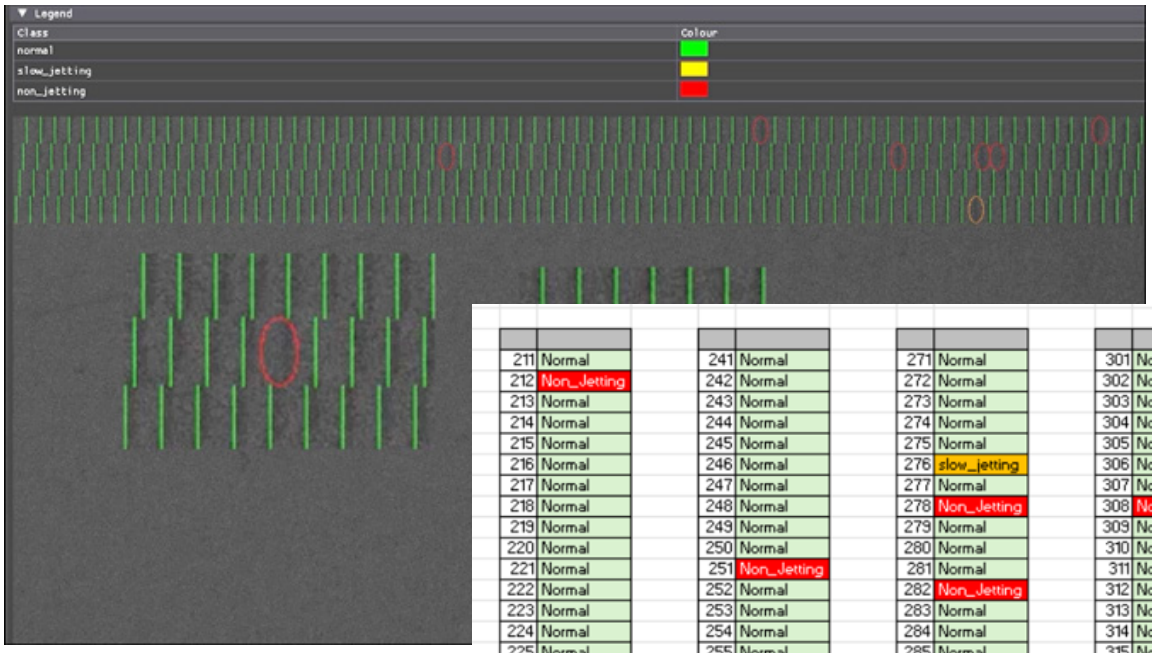
Detection alone, however, is not sufficient in a high-throughput environment. In ceramic tile production, stopping a line can be costly, making it essential to manage defects dynamically wherever possible.

Meteor's NozzleFix™ algorithms use the data provided by Nozzle Health Technology™ to compensate for nozzle failures in real time. By adjusting image data and redistributing ink deposition, the system can minimise visible artefacts and maintain acceptable print quality, particularly in designs where minor variations can be absorbed.

Where necessary, the system can also trigger maintenance actions or halt production to prevent defective output, providing a flexible response based on the severity of the issue. This combination of detection and compensation enables continuous production with greater confidence in output quality.

> "Meteor's Nozzle Health Technology represents a shift towards real-time, data-driven nozzle monitoring."





211	Normal	241	Normal	271	Normal	301	Normal
212	Non_Jetting	242	Normal	272	Normal	302	Normal
213	Normal	243	Normal	273	Normal	303	Normal
214	Normal	244	Normal	274	Normal	304	Normal
215	Normal	245	Normal	275	Normal	305	Normal
216	Normal	246	Normal	276	slow_jetting	306	Normal
217	Normal	247	Normal	277	Normal	307	Normal
218	Normal	248	Normal	278	Non_Jetting	308	Non_Jetting
219	Normal	249	Normal	279	Normal	309	Normal
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221	Normal	251	Non_Jetting	281	Normal	311	Normal
222	Normal	252	Normal	282	Non_Jetting	312	Normal
223	Normal	253	Normal	283	Normal	313	Normal
224	Normal	254	Normal	284	Normal	314	Normal
225	Normal	255	Normal	285	Normal	315	Normal
226	Normal	256	Normal	286	Normal	316	Normal
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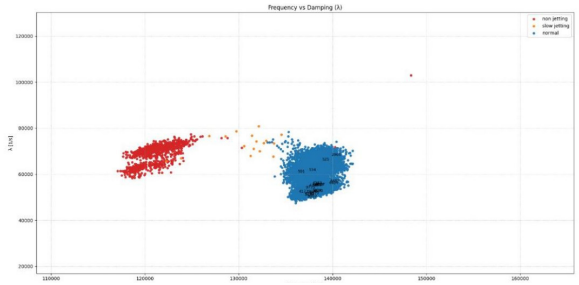

Test results

Testing conducted at a customer site demonstrated the effectiveness of Nozzle Health Technology in classifying nozzle states. The system was able to distinguish between non-jetting, degraded, and normal nozzles with a high degree of accuracy. Across multiple datasets and repeated test runs, the classification accuracy reached 99.4%, indicating a high level of reliability in real-world conditions.

Red – Non jetting

Amber – Slow jetting

Blue – Normal jetting

Conclusion

Nozzle failure is an inherent challenge in ceramic inkjet printing, driven by demanding inks, harsh environments, and the scale of modern production systems. Traditional detection and maintenance approaches are increasingly inadequate for managing this complexity.

By enabling real-time, non-invasive monitoring of nozzle performance, Nozzle Health Technology™ provides a more effective foundation for nozzle management. When combined with intelligent compensation through NozzleFix™, it allows manufacturers to reduce waste, minimise downtime, and maintain consistent print quality.

As ceramic tile production continues to evolve toward higher speeds and greater design complexity, such technologies will play a central role in ensuring reliable and efficient operation.

About the author

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David has been involved with digital printing for over a decade, supporting and bringing to market a variety of industrial solutions including large web, ceramics, direct-to-textile and ink delivery systems. Joining technology and product design consultancy TTP in 2014, David soon moved to TTP Meteor, now Meteor Inkjet. Prior to working in the inkjet industry, David began his career in the RAF as a ground radio electrician working on advanced radar systems, infrastructure and communications.

About Meteor Inkjet

Meteor Inkjet Ltd is the leading independent supplier of industrial inkjet electronics, software, tools and services. Working closely with all major industrial inkjet printhead manufacturers, Meteor offers production-ready solutions to printer OEMs and integrators worldwide.

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