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Industrial Tomography

Detecting hidden defects with microfocus X-ray CT

Industrial manufacturers increasingly rely on computed tomography (CT) for non-destructive testing of batteries, plastics, composite materials, and semiconductor devices. This approach allows the complex internal structures of these materials to be inspected for hidden defects – such as micro-voids, cracks, or inclusions – without damaging components. The X-ray source plays a critical role in CT system design [1], with microfocus X-ray sources enabling high-resolution inspection by minimizing geometric blur and operating across a voltage range suitable for both 2D and 3D non-destructive testing.

The challenge: achieving high-resolution inspection in practice

The growing number of applications for industrial CT systems is driving demand for higher resolution and greater imaging flexibility, creating a number of challenges for system designers needing to balance several competing performance requirements. The size of the X-ray source focal spot is a major limitation, as focal spots in the millimeter range can provide higher output power, but introduce geometric blur, making it difficult to resolve fine features. Microfocus X-ray sources effectively minimize blur and enhance image detail, with the trade-off of lower tube currents that can extend acquisition time [1].

These performance requirements must be addressed at the system level, particularly in how the X-ray source is integrated. Open type sources can deliver higher voltages and output powers for demanding inspection tasks, supporting high-performance applications, while sealed type sources offer a compact, low-maintenance alternative that simplifies integration into industrial CT systems and enables reliable long-term operation. If the source has a monoblock structure, the design also eliminates the need for high-voltage cables. Achieving this balance between focal spot size, output power, and system integration remains a central challenge in the development of industrial CT systems [2, 3].

Advanced microfocus X-ray sources

To address these challenges, Hamamatsu Photonics has developed a complete range of microfocus X-ray sources for high-resolution industrial CT inspection including both open and sealed type microfocus X-ray sources. These components combine small focal spot sizes with high X-ray tube voltages of up to 300 kV (180 kV for sealed types), enabling the detection of fine internal features while maintaining the penetration required for a wide range of materials and component types.

In particular, sealed-type microfocus X-ray sources are well suited to the inspection of batteries, plastics, composites, and semiconductor devices, where both resolution and reliability are critical. Their compact designs simplify integration and reduce the need for additional infrastructure, supporting stable, low-maintenance operation. They also support both 2D and 3D non-destructive testing, allowing engineers to adapt inspection workflows to different application needs, from offline inspection analysis to integration into production workflows [2].

The range includes microfocus X-ray sources based on transmission-type designs [4] also referred to as target-ground (TGND) technology. In this configuration, a thin target is positioned immediately adjacent to the X-ray exit window inside the tube. This allows the effective X-ray focal spot to be located very close to the external surface, enabling the object to be placed closer to the focal spot. As a result, the focus-to-object distance is reduced, leading to higher geometric magnification and improved ability to resolve extremely fine features.

Hamamatsu Photonics also offers a range of detectors for CT applications, including flat panel detectors. This is particularly important for high-resolution imaging, where the performance of the X-ray source must be matched by detector capability to fully resolve fine internal features.

Integration into industrial microfocus X-ray CT systems

Industrial CT platforms are typically supplied as complete inspection systems combining X-ray sources, detectors, motion stages, and reconstruction software, but cost and system complexity have traditionally limited uptake. One European CT system developer set out to address this issue by creating a more compact, flexible, and convenient platform capable of being widely deployed – including closer to production lines – to enable routine inspection of small components.

In this system, the component for inspection is placed on a rotating stage inside the scanning chamber, then the X-ray source and detector capture a series of projection images as the object rotates. These projections are then reconstructed to generate a 3D representation of the component.

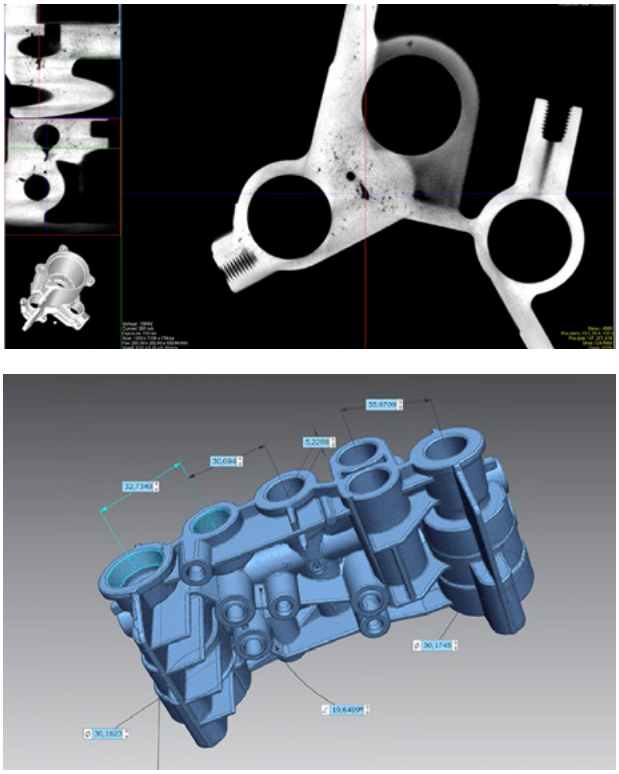
The company chose a sealed type microfocus X-ray source from Hamamatsu Photonics for integration into its compact CT platform, helping to achieve:

- **Improved image resolution**, enabling detection of very small internal defects
- **Higher reliability**, thanks to stable and consistent X-ray output
- **Multi-material inspection**, allowing analysis of plastic, rubber, and metal components
- **Compact system design**, simplifying integration into space-constrained industrial environments

Application highlights

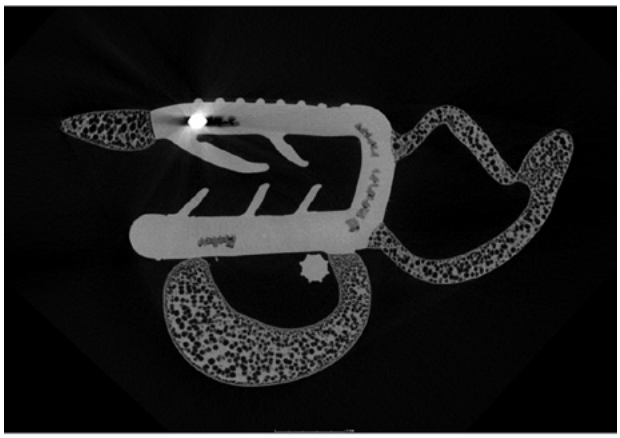
The images below illustrate representative CT inspection results across a range of materials and applications, demonstrating the system's ability to resolve fine internal features and analyze complex structures non-destructively.

Automotive parts inspection



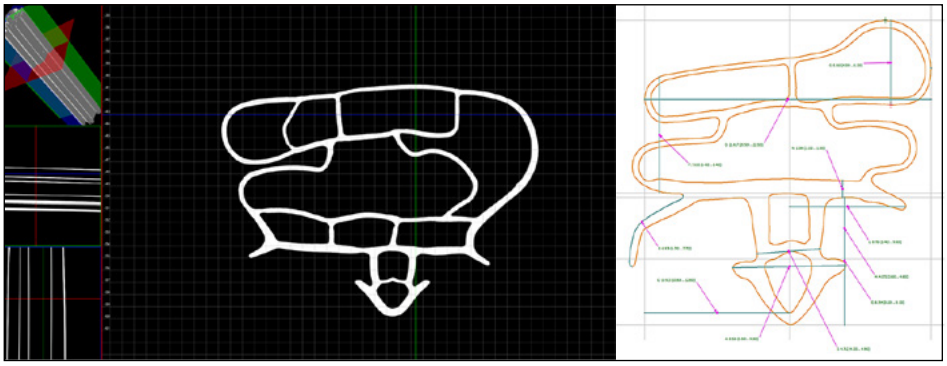
Cross-sectional CT images of an automotive component, revealing internal air bubbles within the object (upper panel), and a 3D reconstruction of the same component (lower panel). Courtesy of MDA S.r.l.

Composite materials with sharp surface structures



Cross-sectional CT image of an object composed of a porous region, a denser region, and a metallic part, which appears as the brightest area in the image. Courtesy of MDA S.r.l.

Deformable rubber items



CT image of two rubber gaskets, demonstrating non-destructive inspection and metrology without cutting or deforming the component. Courtesy of MDA S.r.l.

The future of CT imaging in non-destructive testing

Demand for industrial CT inspection is expected to grow as components become more complex and manufacturing tolerances tighten. This is driving two key directions in system development: higher spatial resolution for applications such as desktop CT and semiconductor inspection, and higher X-ray energies and output powers to enable inspection of larger or denser components. For example, increasing battery capacity is leading to larger and more complex lithium-ion battery structures, requiring higher X-ray energies for effective inspection. In parallel, there is a growing push to deploy CT systems closer to production lines, enabling faster inspection and reducing reliance on off-site analyses. Meeting these requirements depends on continued advances in X-ray source and detector technologies, as well as their integration into compact, reliable inspection systems.

Developments in microfocus X-ray source design are helping to support both higher resolution and improved penetration, enabling CT systems to address an increasingly wide range of industrial applications. Hamamatsu Photonics' development roadmap is designed to keep pace with the key trends shaping industrial CT. The company is actively advancing microfocus X-ray sources and complementary imaging technologies to address these evolving requirements, while also supporting their integration into complete CT systems. Through this approach, Hamamatsu works closely with system integrators as a technology partner, supporting the development of next-generation industrial CT platforms.

For more information on microfocus X-ray sources, please visit www.hamamatsu.com or contact us at info@hamamatsu.eu

References

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