Case study

AI-powered visual quality assessment of CAT substrates

extrusion process

Company profile

Industry
Leading provider of substrate extrusion solutions for catalytic converters, specializing in emission control technologies for the automotive sector.

Product portfolio
High-quality ceramic and metal substrates for catalytic converters, including custom extrusion solutions for various automotive applications.

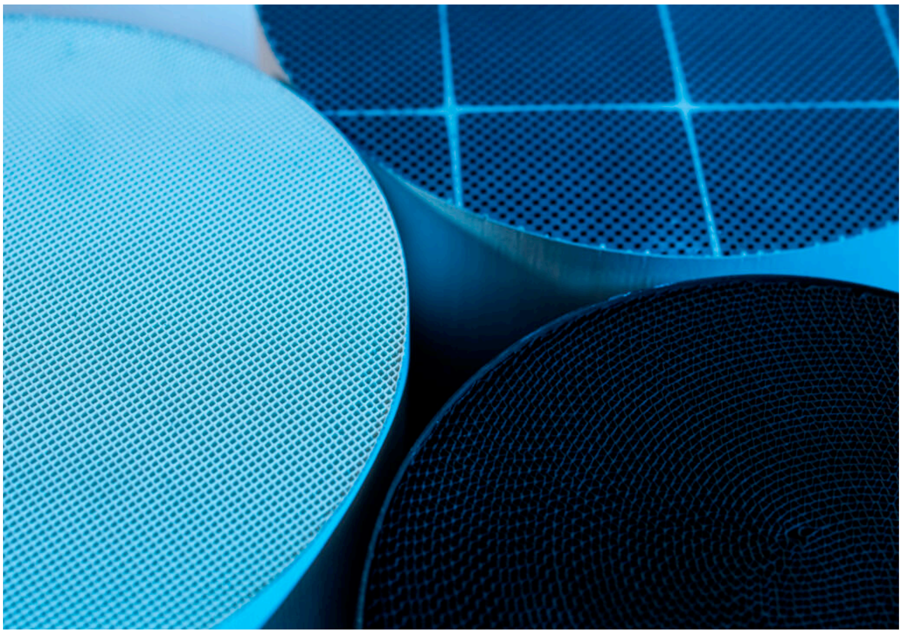
Location
Global operations with production facilities in key automotive manufacturing hubs.

“The inSpect system has truly transformed our process. Its AI is incredibly precise, catching even the smallest cracks and ensuring all substrates are routed correctly. With full automation in place, it is operating around the clock, minimizing human error, and significantly improving our efficiency. ”

- Quality Control Engineer, Substrate Extrusion Manufacturer

Quality assessment of extruded ceramic catalytic converter substrates is critical for the early detection of anomalies that could compromise product integrity or lead to failures in downstream processes. A comprehensive, multilayered inspection covering all measurements—including edges, sides, faces, and the honeycomb structure—ensures that each substrate meets the highest quality standards before moving to the coating process.

By automating the visual inspection, the process becomes more consistent, efficient, and ergonomic, improving operator safety and reducing manual intervention. The system utilizes advanced machine vision technology, integrating scanners and AI-powered area scan cameras to detect defects, even on fragile ceramic surfaces, with minimal physical contact. This non-invasive method maintains the structural integrity of the parts while delivering precise quality control as they progress through the production line.



Key features

Diverse geometries and sizes

The system supports both round and square substrates across a wide range of sizes. With servo-driven components, it dynamically adjusts to varying substrate dimensions, providing comprehensive inspection coverage for diverse geometries on a single production line.

Non-destructive quality assessment

Industrial vision technology inspects the quality of each substrate non-destructively, preserving its integrity while analysing images in real-time as substrates move through the production line.

AI-driven defect categorization

AI-driven algorithms classify defects based on their type and location, including front-face defects like broken cells and cracks, edge defects such as chips, fills, and discoloration, side defects like cracks, and surface deformations, including chips and gauges.

Challenge

The customer's primary objective was to extract the exact substrate dimensions and to detect any deformities that could compromise product quality and result in defective units reaching downstream customers, including coaters, canners, and vehicle manufacturers. The company aimed to implement an in-line, non-destructive quality control system to ensure the correct classification and integrity of each extruded ceramic catalytic converter (CAT) substrate.

The system needed to accommodate round substrates with sizes varying from 142 mm to 330 mm, and square substrates with sizes varying from 150 mm to 230 mm. It was critical to identify defects, such as chips, cracks, gouges, and other irregularities, while also performing detailed geometrical measurements, including circumference at multiple points and wall to face perpendicularity. Additionally, the system had to inspect the internal cell structure for defects like missing walls, filled or compressed cells that could impact performance.

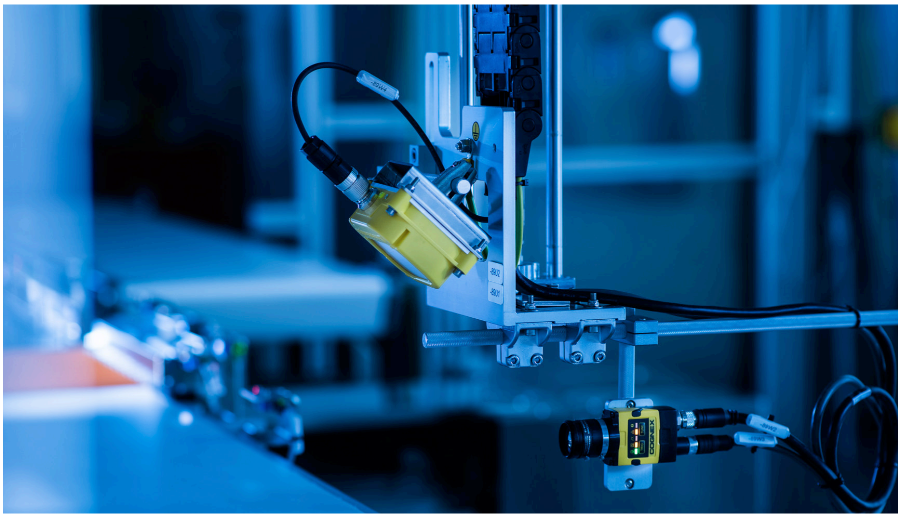
Quality control had to be performed after the substrates had cooled from the furnace hardening process. Full automation was required to maintain or enhance production cycle times, with each substrate being marked and tracked for complete traceability throughout production and subsequent handling stages.

Solution

We developed and implemented the inSpect visual control system to provide a comprehensive quality assessment for extruded catalytic converter (CAT) substrates. Utilizing advanced industrial vision technologies, the system performs precise 2D and 3D measurements.

Servo-driven components automatically adjust to accommodate both square and round parts, ensuring precise inspection across all sizes produced. The fully automated process maintains consistent cycle times, ergonomic operation, and consistent results, with robotic manipulation preserving substrate integrity during inspection.

Our setup utilizes multiple industrial computers with GPUs, ensuring all measurements are processed within the required cycle time. We integrated two control stations along the existing conveyor line, positioned immediately after the substrates are cut to size and cleaned. At the first station, the system simultaneously inspects for anomalies of the substrate's circumference and edges.



Multilayered AI inspection

Crack detection on side walls and top and bottom faces

The system employs U-Net and the segmentation module of the YOLO deep learning model to analyse all surfaces of the extruded substrates. It accurately distinguishes between cracks on the perimeter, edges, and end faces, ensuring comprehensive surface inspection.

Deformed or filled cell walls

The system analyses structural patterns within the cells. The AI model reconstructs what the cells should look like and isolates defects by comparing the predicted structure with the original. To differentiate between filled cells and missing walls, we use a multi-class object detection algorithm with segmentation, followed by precise identification of defective cells.

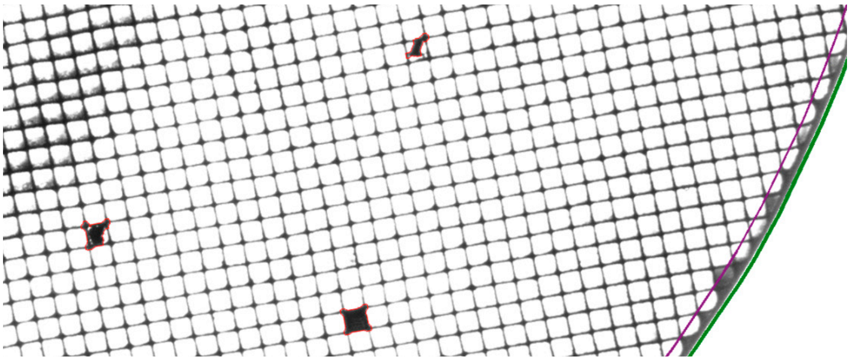
Material loss or chipping at the edges

The system reliably detects edge defects by either analysing 3D profiler data or using an AI-enhanced camera system to flag irregularities. The volume of missing material is calculated using profile data, ensuring accurate edge inspection.

Laser sensors and profilers measure circumference at three points (beginning, middle and end). Substrates are rotated by servo-driven clamps until the system identifies the barcode which serves as a reference point for aligning the honeycomb structure. The precise angle of the honeycomb allows the system to ensure alignment, parallel to the inspection surface, which is critical for detecting defects, especially cracks.

Optimized lighting, activated in a strategic sequence, improves crack detection. This approach is also employed for identifying chips and gouges that could affect CAT performance.

The second station conducts two inspections: it checks for surface defects and examines the honeycomb cell structure for missing walls, filled or compressed cells.

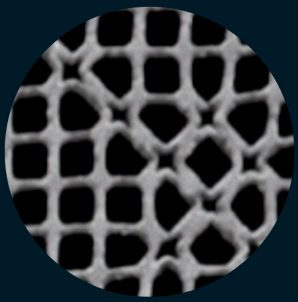


Laser sensors and profilers assess the perpendicularity of the top and bottom faces relative to the side walls, and the side walls themselves are scanned by servo-driven laser profilers positioned beneath the cameras to analyse their perpendicularity. The outcomes indicate if the substrate walls are tilted.

Both stations are equipped with AI-powered industrial cameras and LED lighting, using a combination of analytical and AI-driven inspection techniques. Traditional mathematical methods analyse precise geometric measurements such as circumference and perpendicularity. Meanwhile, AI detects potential anomalies and defects on the substrate's side walls, top and bottom faces, and internal honeycomb structure, including side cracks, scratches, edge chips, and issues like missing cell walls or compressed cells. The system inspects the surface area by generating point clouds to identify discrepancies. Deep learning algorithms further assess the depth, area, location, and volume of defects across all surfaces, enabling accurate evaluations.

The AI-driven system processes captured images quickly, evaluating both entire substrates and detailed sections for faster, thorough inspection. The entire inspection, from data acquisition to analysis and communication, reaches the 15 second cycle time, allowing real-time sorting of substrates as "OK" or "NOK." Depending on the identified anomaly or defect, extruded substrates can be processed and repurposed as smaller dimension components.

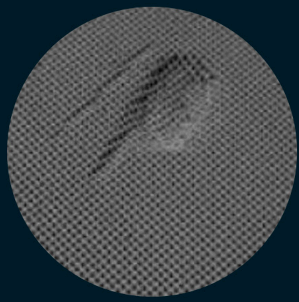
All inspection data, including images and parameters, is stored to ensure full traceability of each substrate, its status, and any detected defects. The system is fully integrated with SCADA for seamless data management and monitoring.



High-resolution 2D vision system

The 2D vision control station features three 25 MP industrial cameras with a frame grabber to capture precise, high-resolution 2D images. Its primary function is to detect surface defects on the substrate's top and bottom face, such as broken cells and cracks, as well as edge defects including chips, fills, and discoloration, and side defects like cracks.

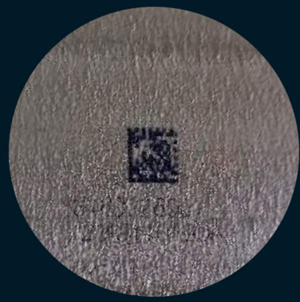
The system captures a comprehensive set of 25 MP RGB images for each part: six images in total for square parts (two each of the top and bottom faces and four side images while rotating), and ten images for round parts (two each of the top and bottom faces and eight side images, taken at 45-degree intervals during rotation).



3D scanning with laser profilers

The 3D measurement system, designed for inspecting the circumference and perpendicularity of substrates, is equipped with five precision laser profilers and two frame grabbers, achieving an accuracy of 0.01 mm. The system offers per-pixel resolution ranging from 0.05 to 0.1 mm, enhancing the precision of length, edge length, and angularity measurements through mathematical methods.

The 3D point cloud is generated through laser profiling. A laser line projected onto the substrate is captured by an area scan camera, which analyses the deformation of this line in the captured images. This analysis allows the system to calculate the distance at each point along the line, creating a detailed 3D point cloud of the object's surface.



Automated data reporting

The entire inspection process—data acquisition, analysis, raw data storage, and communication—finishes before the next substrate arrives. Our vision system ensures 100% reliable tracking with laser-etched data matrix codes (DMCs) and supports seamless transitions between continuous and indexed transit modes to meet cycle times. It integrates cameras that read DMCs, OCR, and barcodes across various positions.

All inspection data, including images and parameters, is stored systematically, with automated reporting for streamlined documentation and quality assurance. The solution features an intuitive vision software interface and a SCADA system for full machine control, ensuring quick integration and minimizing installation downtime.

Results

Inspection automation has refined measurement accuracy, ensured thorough inspection of all substrates and improved product quality. By measuring the circumference at three strategic points and assessing wall perpendicularity, it confirms that each substrate adheres to the geometric tolerances required for subsequent canning operations. Additionally, the line is adept at processing various substrate shapes and sizes, enhancing time efficiency and spatial utilization. With the adoption of full automation, operators previously tasked with quality assessment have been reassigned to higher-value tasks, improving their work ergonomics and overall production efficiency.

0.01 mm

accuracy and precision

Geometric parameters are measured using point cloud data of the entire substrate, achieving a precision of 0.01 mm.

5 FTEs

reduction per production line

Redirecting operators' involvement from the quality control process to other, higher value-added tasks.

100%

substrates inspected

All substrates undergo full in-line inspection, ensuring complete quality control and adherence to stringent production standards.

67%

fewer items incorrectly sorted

Sorting accuracy has tripled, reducing incorrect substrates per batch by two thirds compared to the previous process.