Automatic X-ray inspection of temperature sensors

KYOCERA AVX Components (Dresden) GmbH is the competence center for temperature, pressure, and liquid sensors of the KYOCERA AVX Group. For more than 25 years, sophisticated product and process developments have been created for well-known automotive manufacturers and system partners and then transferred to the company's production facility located in Klingenberg near Dresden.

Ensuring quality with X-ray

X-ray inspection is one of the methods used to ensure product quality. For example, X-ray systems are used for the inspection of temperature sensors to detect defects in the outer casing and inside the sensor early in the production cycle.

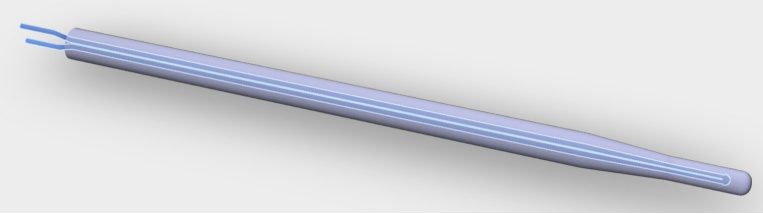

Figure 1: Temperature sensor (source: GÖPEL electronic)

Previously, this was done using manual X-ray systems (MXI). Several temperature sensors were manually inserted into the system and manually assessed by specialized personnel. Due to the constantly increasing demand, this process needed to be automated. The aim was to acquire an automated X-ray system (AXI) that can load and evaluate several temperature sensors automatically. The cycle time of 4s per sensor was not to be exceeded. After an extensive benchmark with several AXI manufacturers, the X-Line from GÖPEL electronic was selected. Minor modifications were made to the system to enable it to fully inspect the temperature sensors in multi-shift operation.

Carriers with 3D printing

In order to be able to automatically load and inspect up to forty temperature sensors, GÖPEL electronic first had to develop a suitable carrier. It had to be light, stable and as flexible as possible to accommodate sensor lengths from 60mm to 150mm. Ergonomics and durability were also considered. "We decided in favor of carbon as the base material in combination with 3D printed components and milled plastic elements", says Andreas Türk, Product Manager X-ray Systems at GÖPEL electronic. "This combination is light, stable, and cost-efficient. In addition, the base plate, made of carbon, is almost transparent in the X-ray image due to its low density", says Türk. Several of these 420mm x 200mm carriers are in circulation in the manufacturing process and up to three carriers are in the X-ray system at the same time. "We have a three-part transport system in the X-Line. This

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allows us to load, unload, and inspect in parallel. This saves handling time and thus reduces the overall cycle time ", adds Türk.

The sausage flipper

In order to increase the test depth, it was necessary to irradiate the pin-shaped temperature sensors from different directions. To achieve this, a motorized unit with a rubberized push rod was integrated into the system. The push rod makes it possible to rotate all forty temperature sensors simultaneously by a few degrees. In the inspection process, three successive X-ray images are taken. After the first X-ray image is taken, all temperature sensors are rotated a few degrees by the push rod and a second image is taken. The sensors are then rotated again by a few degrees and the third and final X-ray image is taken. By evaluating images taken from three different rotational angles, the amount of detail available for analysis can be increased enormously (not all failures can be found by inspecting from just one direction). GÖPEL's internal working title for this customized rotation unit was "the sausage flipper" - fitting for the company based in Thuringia, the land of bratwurst.

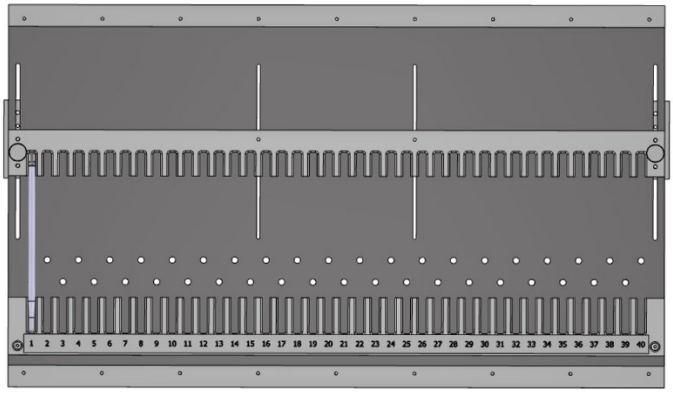

Figure 2: Carbon carrier with 3D printed parts (source: GÖPEL electronic)

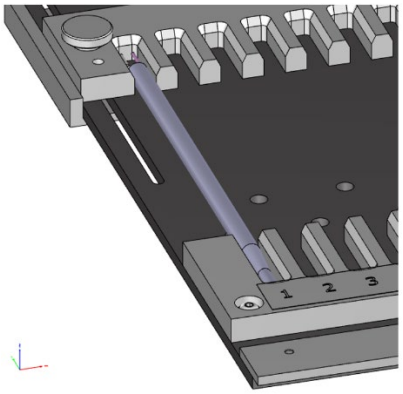

Figure 3: Carrier with a temperature sensor (source: GÖPEL electronic)

Another aspect contributing to the success of the project is the X-ray imaging itself: the images are captured using digital line scan detectors. This was the only way to maintain the cycle time requirement with a high resolution of approx. 10µm/pixel.

Inspection with artificial intelligence (AI)

The recorded X-ray images are analyzed in several project-specific test functions. In addition to the tip of the temperature sensor, the closure at the lower end must also be inspected. There are separate measurement and inspection tasks for each area. In the area of the sensor tip, the wall thickness, the distance between the inner wires and the inner wall, the welding of the wires, and the thickness of the sensor tip are tested, among other things. In the area of the closure at the end of the sensor, wall

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thicknesses and distances are also tested, as well as the protrusion of the enclosure material in several directions.

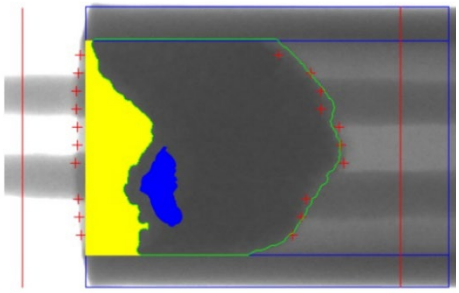

Figure 4: Evaluation of the sensor closure for shape, protrusion and inclusions. (source: GÖPEL electronic)

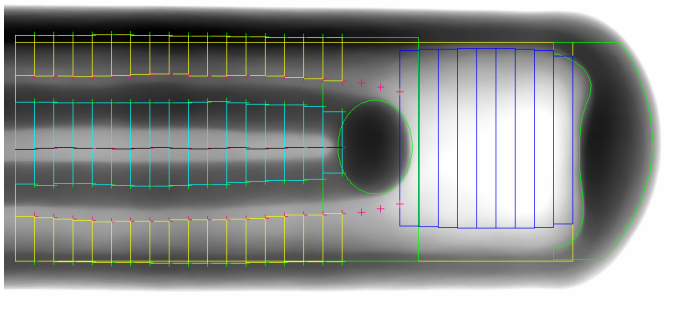

Figure 5: Inspection of the sensor tip. Among other things, distances, thicknesses, and the welding of two wires are checked. (source: GÖPEL electronic)

"We were able to solve the majority of the customers requirements using conventional image processing", says Winfried Löther, head of the artificial intelligence project team at GÖPEL electronic. "However, one inspection task was very difficult to realize using standard approaches. For this reason, we trained an AI model for this", continues Löther. It involves the evaluation of a welded joint. Here, two wires must be welded together inside the temperature sensor. This assessment is quite simple for humans, but complex for the machine, as the joint is always shown from different viewing angles. This is where artificial intelligence helps. "To train the AI, we used a large number of real and simulated images to make the AI model robust," explains Löther. Parameterizing the AI test function is particularly easy. This works without any configuration parameters and is activated with just a few clicks.

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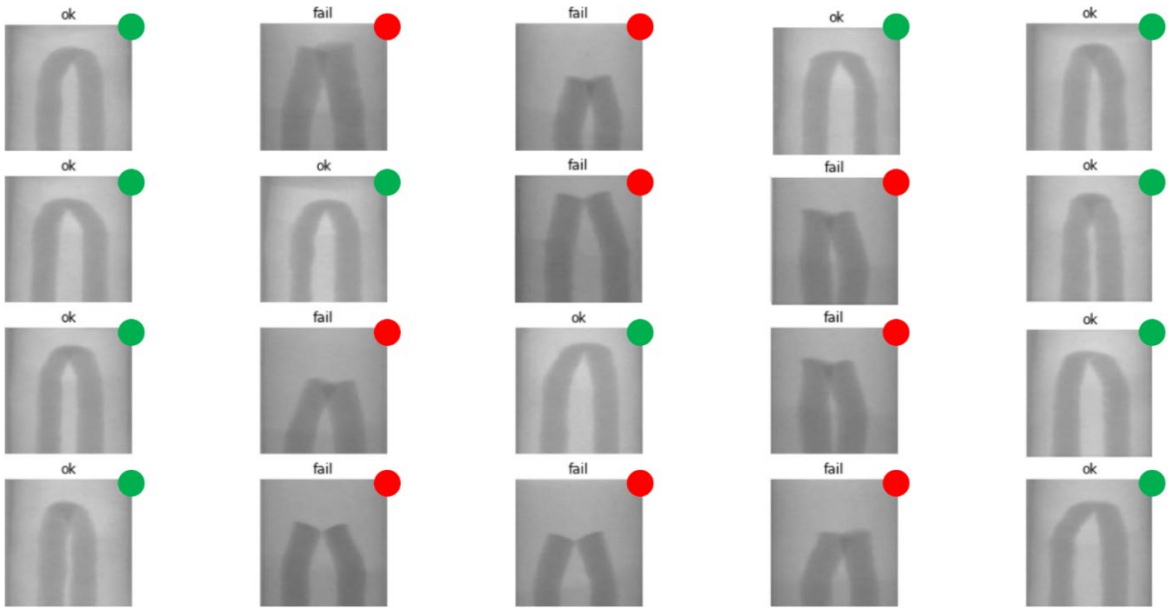

Figure 6: An AI model evaluates the welding of two wires. Implementing this task can with conventional image processing would require great effort and many parameter settings. With AI, the inspection is carried out with just a few clicks. (source: GÖPEL electronic)

Turnkey solution

The AXI system was to be seamlessly integrated into the production environment at KYOCERA AVX Components. The decision was made in favor of an off-site solution consisting of an AXI system with two external conveyor modules and a separate verification station for inspecting and removing any faulty parts.

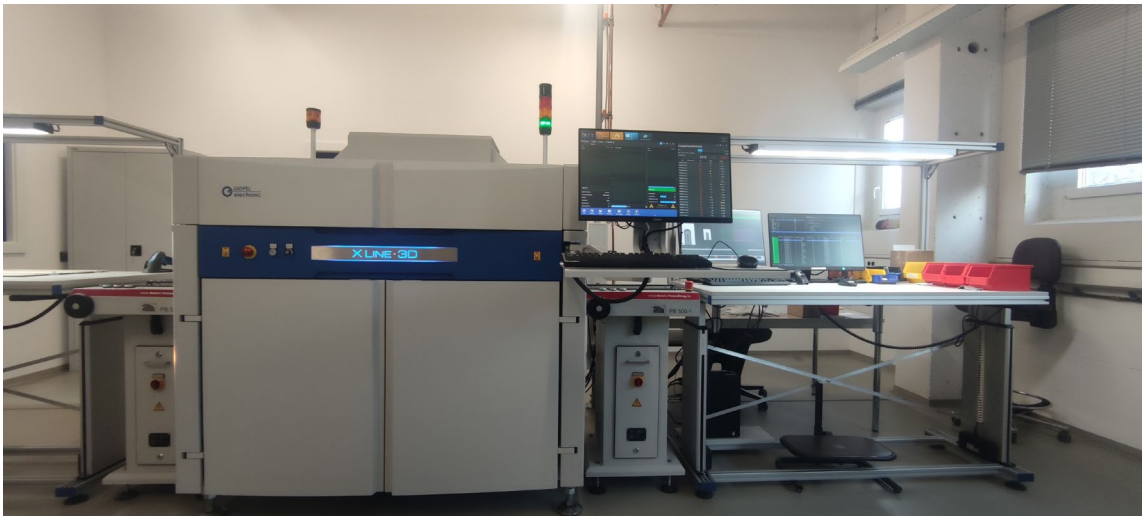

Figure 7: AXI system at KYOCERA AVX Components (source: KYOCERA AVX Components (Dresden) GmbH)

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The work flow starts with the reading of the material and production order numbers from an order form using a hand-held scanner mounted on the AXI. The X-Line system uses this data to load the appropriate test program. The operator then places a loaded carrier on the input conveyor in front of the AXI system. The serial number of the carrier is read with a permanently installed code reader and automated loading and inspection begins. All inspection results are stored with the serial number in a database. This ensures that any failure found can be clearly assigned to the corresponding carrier at the downstream verification station. It is then very easy for the operator to evaluate any failures that are found. In addition to the X-ray images, measured values are also available. Compared to manual inspection, a significantly higher throughput is achieved with increased inspection coverage. In addition, fully automated inspection by the AXI machine eliminates fatigue of a human operator as a potential source of errors.

Summary

GÖPEL electronic has installed an automated X-ray system (AXI) for the inspection of temperature sensors at KYOCERA AVX Components (Dresden) GmbH as a turnkey solution. In addition to customized hardware, GÖPEL electronic provided AI-supported inspection functions for examining the sensors.

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