Technical Paper

100% quality control and traceability at component level meet artificial intelligence

Brief summary
Information about the production sequence and traceable quality all the way down to component level: manufacturers of punched and stamped parts have to meet demanding requirements and vastly step up their quality control. Technologies based on artificial intelligence (AI) have already been used to achieve these goals for several years: they provide support for boosting product quality and at the same time, they make quality inspection more efficient. To achieve the maximum possible benefit, the technology must meet two essential requirements: it must allow integration into existing machinery and plants, and it must be possible to combine it with unique identification of the parts. Manufacturers in the punching industry can now take advantage of high-performance optical inspection systems that utilize special illumination and imaging techniques, AI-based anomaly detection, and identification methods such as laser marking from Kistler. With equipment of this sort, they are well placed to meet the challenging requirements for quality, efficiency and end-to-end part traceability – and they can implement 100% quality control instead of inspection based on random part sampling.

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1. Optical quality inspection with the "shape-from-shading" method

"Shape-from-shading" is an optical inspection method that allows precise monitoring and checking of individual parts in the punching sector. It makes use of special illumination and imaging technology to separate information about the texture of an inspected part from its topological characteristics. This process even makes it possible to see the most minute anomalies in individual parts that would remain undiscovered with other methods.

To achieve this, the part to be inspected is illuminated from several directions and captured by a camera. This results in images where light and shade are distributed differently. These (real) individual images can then be taken as the basis for calculating various topographical images which only show the 3D information about the surface of the inspected part. This makes quality inspection independent of changes in the surface of the inspected part, such as color or brightness differences that would show up clearly in the texture image and would prevent stable evaluation. Even scratches, cracks or indentations with heights or depths of only a few micrometers can be detected reliably with the "shape-from-shading" process and conventional image processing methods (Figure 1, Figure 2).

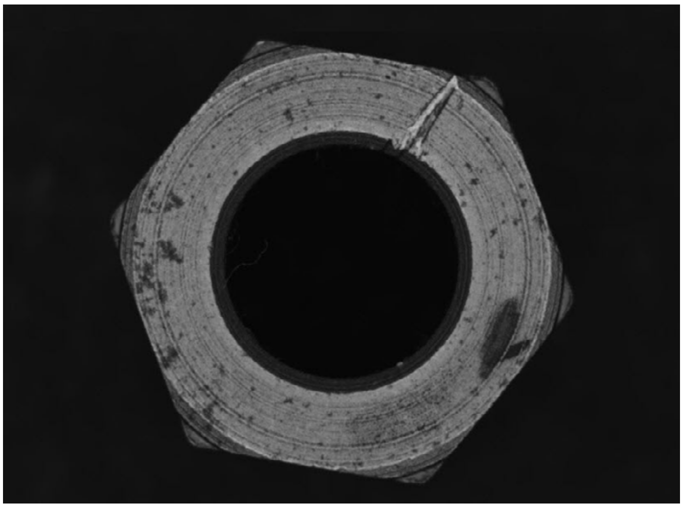

Fig. 1: Texture images do not allow reliable statements about possible faults, because they may not be visible. Color or brightness differences also interfere with stable evaluation.

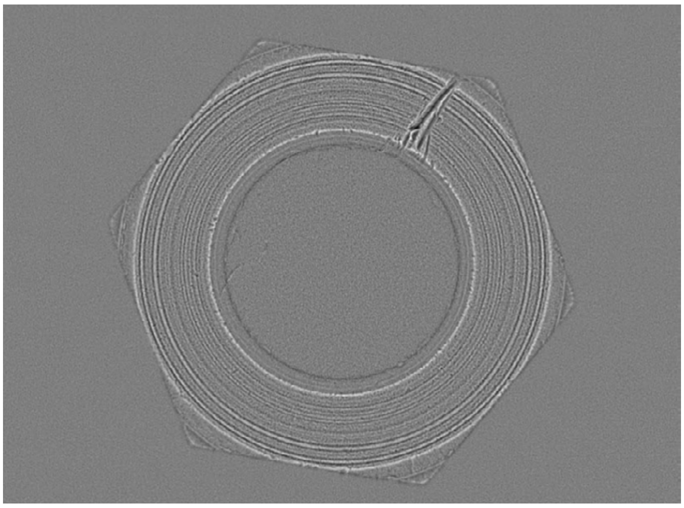

Fig. 2: Inspection images created with "shape-from-shading" also allow stable evaluation of minute faults such as scratches or scoring.

Thanks to the special LED illumination, this method functions with very high stability for both dark and shiny surfaces. Ingenious algorithmics compensate for motion, so the method can also be applied to moving objects: this allows it to be used in automated inspection technology with high part throughput rates (Figure 3).

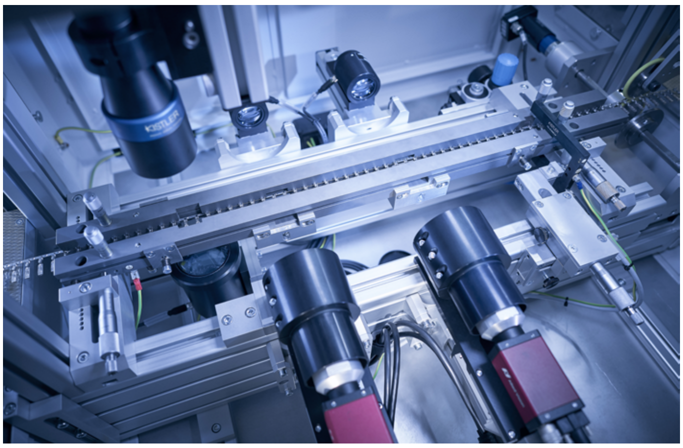

Fig. 3: The "shape-from-shading" process is integrated into this punched part test cell.

2. Detecting anomalies with the help of artificial intelligence

The AI-based anomaly detection process is used to inspect and evaluate the captured images. This is a special technique based on deep neural networks (DNNs). To be more specific: convolutional autoencoders (Figure 4) are deployed in combination with differential image generation so that unusual or unexpected deviations in images of inspected parts become visible. The strengths of this type of anomaly detection come into play precisely where conventional image processing reaches its limits, or at least requires a high degree of expertise: fault detection in complex textures. Neural networks are often the only option on account of the variability among good parts, and because the decision criteria for OK and NOK parts cannot always be mapped mathematically.

So that anomaly detection can be utilized, the software first has to be taught. To begin with, the deep neural network is fed with images of OK parts, so it "learns" their characteristics and becomes capable of reconstructing them as exactly as possible. A vast quantity of data is available to users here because they produce enormous numbers of OK parts. Provided that the anomaly is easily recognizable, the neural network can be trained equally well with color or black-and-white images and with depth or curvature images.

This method of detecting anomalies makes use of the fact that the trained autoencoder cannot reconstruct divergent image content and structures. Therefore, the reconstruction of an inspected part with an anomaly will no longer include the anomaly but instead, will look like the corresponding good part. All that is then needed is to establish the difference between the input and output images in order to obtain the actual anomalies (Figure 5, Figure 6).

They can then be classified by applying conventional image processing methods, or with an additional neural network if necessary. Once such an anomaly has been identified, the AI software triggers separation of the part as appropriate. After a few production batches, users can feed the software with more images of OK parts that may have different characteristics than the parts inspected in the first round. In this way, users can continue to refine the AI – and they can also minimize the percentage of pseudo scrap.

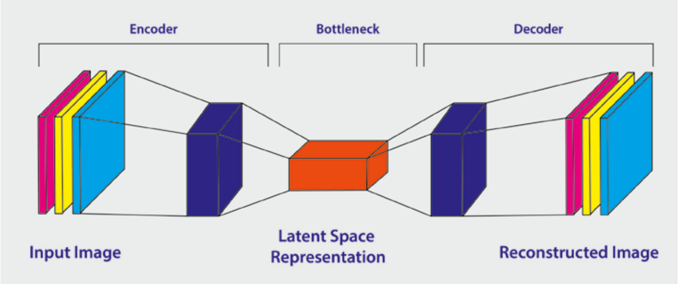

Fig. 4: Schematic view of a convolutional autoencoder.

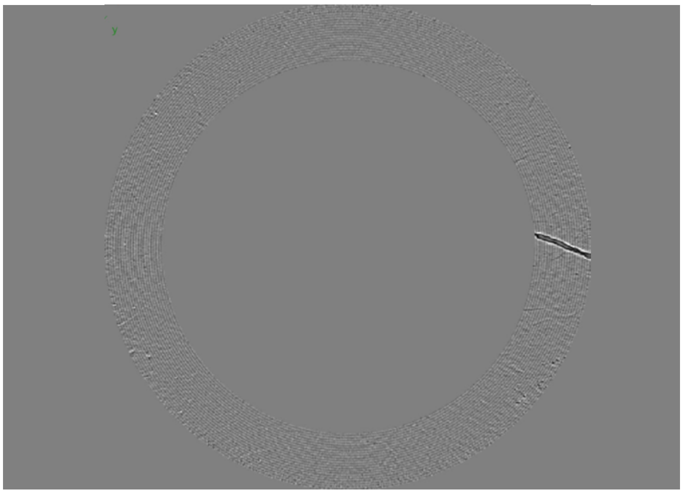

Fig. 5: Example of an inspection image created with the "shape-from-shading" method.

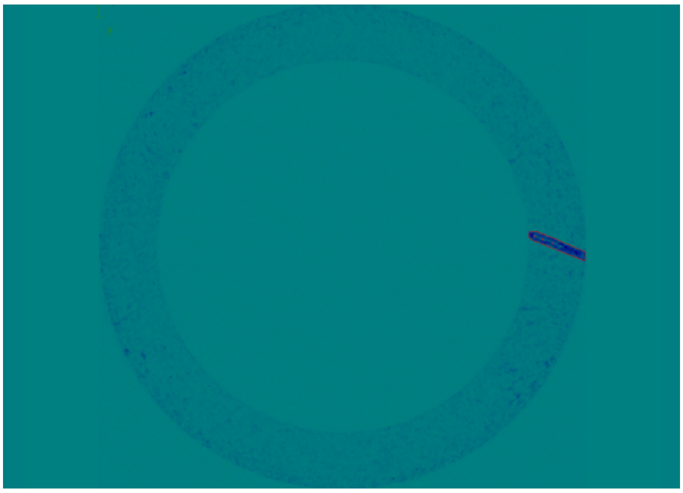

Fig. 6: Evaluation of the image with the help of anomaly detection.

3. The future of artificial intelligence in quality assurance

By deploying artificial intelligence in quality assurance, manufacturers can achieve great advances – especially as regards unusual defects or those that only occur sporadically. The parameters defined in advance for conventional rule-based inspection methods often fail to identify these defects, so parts with faults of this sort remain undetected and are not separated out. Going forward, therefore, manufacturers will in all probability use a combination of conventional rule-based and AI-based methods – because one of these processes cannot replace the other one.

4. Laser marking of individual parts and documentation

Precise marking of the individual parts that were found to be correct after inspection is one of the key factors in the efficient design of quality assurance and the extensive documentation that goes with it. This allows manufacturers to implement their quality assurance right down to part level, and to document it comprehensively. The punching industry marks parts continuously as they pass through the line – so the marking-on-the-fly (MOF) method is used. This means that the laser system downstream of optical monitoring has to meet special requirements for marking speed. For example, the LASERmark KLM 621 marking cell used by Kistler in a quality assurance combination is based on the latest fiber lasers. This cell meets the various requirements: short marking time to ensure cost efficiency, lowest possible positioning tolerance for the marking field, and optimal contrast conditions. In the marking-on-the-fly process, the laser cell achieves output of over 2,500 parts per minute. The high-precision Kistler trigger sensor ensures a reproducible positioning accuracy of < 0.01 mm. Thanks to continuous marking or coding of all produced parts, this method allows efficient and complete part traceability (Figure 7).

Fig. 7: With a laser marking system from Kistler such as the KLM 621 shown here, markings can be applied to as many as 2,500 parts per minute.

5. Documentation, presentation and evaluation thanks to the OPC UA interface

The increase in quality requirements as such has been matched by more demanding standards for the level of detail and completeness of the documentation. Comprehensive, detailed recording and storage of relevant data for produced and marked parts are also mandatory requirements for manufacturers in the punching industry. Networking of all the relevant machines is the essential basis here – not only for efficient data management followed by analysis of the data for process optimization, but also for complete traceability at part level.

Kistler has responded to this need by taking umati (the universal machine technology interface) as the basis for integrating an OPC UA interface into all the solutions in its Vision Inspection business line. Networking the system with the machines around it also makes it easier to implement comprehensive process monitoring. The system stores the relevant documents for the individual parts in a database. Thanks to this approach, users can advance the development of their quality inspection from a random sample database to complete inspection and traceability of the manufactured parts. Depending on the specific application case, both machine data and inspection results are presented, analyzed and statistically evaluated in real time, or stored for evaluation at a later time. In conjunction with analysis software tools such as MaDaM and jBEAM, for example, users can analyze quality, production and measurement data at any time from any location, with access from the correct instance. This eliminates error sources and unnecessary distances. At the same time, users can take advantage of the data for ongoing process optimization in production.

Accurate inspection and testing of individual parts with continuous improvement based on the use of artificial intelligence and traceability of produced parts guaranteed by individual marking and documentation: thanks to these benefits, manufacturers can meet the requirements expected of them. As well as complying with quality standards, they can maximize the efficiency of their production – and at the same time, they can guarantee individual traceability of the parts they produce.

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